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Special Report - Supplying the Power Grid

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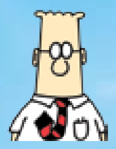

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PSDNA Green Power ENERGY EFFICIENCY

Smart Grid, Smart Move

The smart grid is certainly major news these days - fuelled by the media and government administrations. It finally seems the message has been grasped as promises of energy diversity and, perhaps more importantly, those of hard cash in terms of funding look like becoming a reality.

In addition to the much needed major overhaul of the U.S. electricity grid there is a strong lobby to encourage the development and integration of renewable sources of energy such as wind and solar. President Obama certainly has indicated his support and commitment for green energy and his administration is part of a concerted effort to help the industry grow. Hopefully this is good news for aspiring green-power engineers, generates green jobs as well as green power and is not just another example of a government paying 'lip-service' to a popular policy. The level of actual investment from government, industry and venture capitalists will be a clearer indicator.

The existing grid has difficulty in handling the loads it has today, let alone those of the future. It needs to be upgraded and equipped with the capability of power transmission over long distances, requiring a massive program of building electricity systems that connect remote wind and solar farms to towns and cities, a 'smarter' grid that is more responsive to normal variations in supply and demand.

Smart grids offer a solution, not just by playing a bigger role in achieving environmental goals, but in securing supply and facilitating effective load management. New technologies have the potential to change business models, create new markets and transform the power supply scene.

The world merchant power supply market is projected to decline by over 15% in 2009, with the industrial power supply sector falling in excess of 30% according to the latest analysis from IMS Research which forecasts that nearly all power supply sectors will decline in 2009, the largest fall predicted in industrial applications. In fact, the only sector during 2009 expected to grow is lighting, driven by a strong demand for AC-DC power supplies used in LED lighting applications.

With many suppliers trying to address LED lighting applications such as street lighting and signage boards, strong growth should continue as more and more applications adopt or convert to LED technology.

The future looks bright for smart grid and LED lighting. Let's hope the 'doldrums' in the rest of the industry will be short-lived and responsibly handled by all those making decisions for the future of power electronics and its professionals.

Enjoy this full issue, keep the feedback coming and check out our fun-site, Dilbert, at the back of the magazine.

All the best!

Cliff Keys.

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AIAG Appoints Executive to Board of Directors

The Automotive Industry Action Group (AIAG) has appointed Brian J. Small, General Motors Corporation to the board of directors.

"The appointment of Brian to the board demonstrates AIAG's commitment to and recognition of the need for solutions to drive costs and inefficiencies out of the automotive supply chain," said Brian Vautaw, AIAG board Chairman. "He has extensive experience in supply chain operations with GM and offers practical insight on the current environment and pressing issues facing the industry."

Small began his career with GM in 1979 with the Cadillac division. Throughout his tenure with GM he has held a wide variety of positions in the following areas: Field Sales and Service, Business Management,

Advertising, Marketing, Service Operations, Sales Promotions, Incentives, Events Management, Regional Sales, Service and Marketing Leadership, and Vehicle Distribution.

In 2007 Small was appointed General Director Global Order Fulfillment. His role was expanded in May of 2009 to include oversight of the Global Supply Chain Center in GM's Global Purchasing and Supply Chain organization. He currently oversees GM's global order fulfillment, supply and demand alignment, and GMNA Order Fulfillment operations.

An AIAG member since 1984, General Motors has played an integral part in developing many standards and guidelines that are used globally to drive cost and complexity from the automotive supply chain.

www.aiag.org

Repower Opens New HQ in Denver for US Subsidiary

REpower USA Corp., the wholly-owned subsidiary of German wind energy manufacturer REpower Systems AG, will have a new US headquarters location beginning in early September. The US office for all administrative, sales and project management functions, previously located in Portland, Oregon, will move to Denver, Colorado.

Steve Dayney, CEO of REpower USA Corp., explains: "Since 2007, we have managed our US wind energy business from a Portland, OR office located near our initial projects in California, Oregon and Washington. Today we are seeing our business grow rapidly to other regions of the US. To maintain REpower's future competitiveness and meet our customers' needs in the growing US marketplace, it is crucial to be strategically located and close to all our customers and projects. Denver – centrally located, with an

excellent national and international transportation infrastructure and supportive business climate, provides those characteristics we believe will help us succeed in meeting our US business goals."

Initially, the Denver office will be made up of about 25 relocating or newly hired employees. The staff level is expected to double within the next twelve months at the new Denver office, depending on the overall US wind energy market. The company will also maintain a presence in Portland.

To date, REpower USA Corp. has installed or sold over 300 wind energy turbines with a total rated output of more than 600 megawatts (MW) in the United States.

REpower customers in the US include enXco, a subsidiary of EDF Energies Nouvelles, John Deere Renewables and Cannon Power.

www.repower.de

US Department of Energy Provides Funding for Superconductor Smart Grid Projects

American Superconductor Corporation, a global energy technologies company, announced that the United States Department of Energy (DOE) has provided more than $12 million in funding to AMSC under the American Recovery and Reinvestment Act to complete the following ongoing superconductor smart grid projects: AMSC is receiving $4.8 million in additional funding to develop a three-phase 138kV fault current limiter (FCL) using the company's 344 superconductors.

This FCL will feature a proprietary Siemens-developed, low-inductance coil technology that makes the FCL invisible to the grid until it switches to a resistive state. AMSC is serving as project manager and wire supplier. The team also includes Southern California Edison, Siemens AG, Nexans and Los Alamos National Laboratory. In total, the DOE is providing nearly $8 million in funding for this project.

AMSC is receiving $7.6 million in additional funding for the second phase of its superconductor power cable project with Long Island Power Authority (LIPA). This will be a transmission voltage (138kV) extension of the superconductor cable system that was commissioned in LIPA's grid in April 2008. The extension utilizes AMSC's second generation (2G) high temperature superconductor (HTS) wire, branded as 344 superconductors. AMSC is serving as project manager and wire supplier, Nexans is the cable manufacturer and Air Liquide Advanced Technologies U.S. LLC is providing the cryogenics system. In total, the DOE is providing more than $12 million for this project.

AMSC's awards were part of a $47 million "smart grid demonstration" package announced yesterday by the DOE. According to the DOE announcement, "The $47 million in Recovery Act awards announced today will support existing projects that are advancing demonstration-scale smart grid technologies which will play an important role in modernizing the country's electricity grid." In addition to the $12 million in funding for AMSC's projects, an additional $8 million was awarded to another superconductor fault current limiter project.

HHI's first 1.65 MW doubly fed induction wind turbine in Ulsan, South Korea.

Hyundai Heavy Industries orders Initial Wind Turbine Electrical Systems from AMSC

American Superconductor also announced that it has received an initial order for 17 sets of full wind turbine electrical systems from Hyundai Heavy Industries Co., Ltd. Based in Ulsan, South Korea, HHI is the world's largest shipbuilder, a global leader in turnkey power plants and offshore projects, and a major global supplier of high voltage electrical equipment.

HHI will use the electrical systems in 1.65 megawatt (MW) doubly fed induction wind turbines it will be producing under a license from AMSC's wholly owned AMSC Windtec™ subsidiary. In addition to the 1.65MW wind turbine designs, HHI also has a contract with AMSC Windtec for 2MW doubly fed induction wind turbine designs. HHI's marketing and sales rights for both wind turbines extend to most countries around the world, including those in North America.

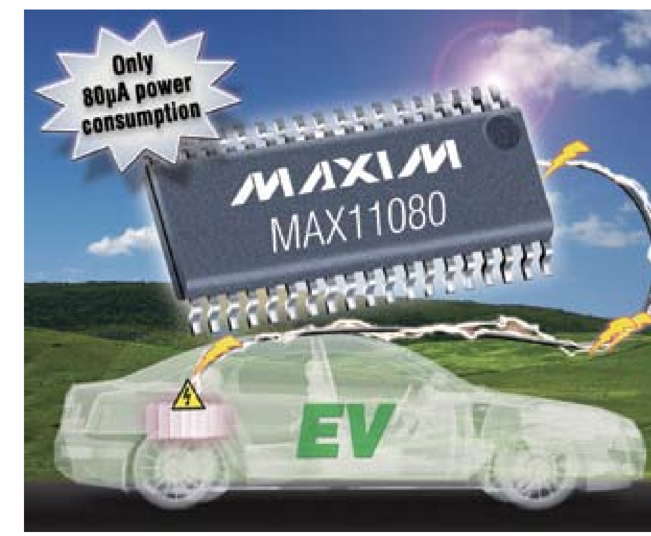
The 138kV AC superconductor power transmission cable operating since April 2008 in Long Island Power Authority's grid.

www.amsc.com

Maxim's New Battery-Protection IC

Reduces BMS Cost by 80% in HEVs

Maxim Integrated Products has launched the MAX11080, a high-voltage, 12-channel battery-protection IC for high-cell-count lithium-ion (Li+) battery stacks. The first stackable fault monitor on the market, this device provides redundant cell monitoring to prevent Li+ batteries from exploding (thermal runaway). Up to 31 MAX11080s can be daisy-chained together to monitor as many as 372 cells. This capability prevents cascading electrical failures and eliminates the expensive isolation components required by discrete solutions. In a typical hybrid car, Maxim's solution reduces the cost of the battery-management system (BMS) by up to 80%.



Offering world-class accuracy, ultra-low power consumption, built-in safety and self-diagnostic features, and plenty of configurability, the MAX11080 solves the problems associated with safely monitoring large battery stacks. It is well suited for a spectrum of battery applications including automotive, industrial, power line, and battery backup.

Bringing Down the Cost of Safety

Today battery pack designers invest a tremendous amount of time and resources to ensure the absolute safety of their stacks. Typical protection circuits employ multiple 3- or 4-channel fault monitors with costly galvanic isolators between the monitors and an assortment of analog and passive components (resistors, multiplexers, etc.). These circuits are bulky and costly, not to mention time intensive.

The MAX11080 greatly simplifies the design of high-cell-count battery packs. A 12-channel fault monitor, this device employs a proprietary capacitor-isolated daisy-chain interface to minimize component count and cost. This unique architecture allows up to 31 devices to be connected in a series stack to monitor as many as 372 cells. Meanwhile, the capacitor-based interface provides extremely low-cost isolation from one bank of batteries to the next, eliminating cascading electrical failures.

Additionally, the MAX11080 offers a 10x reduction in power consumption (80µA operating mode) to conserve battery life. A unique built-in shutdown feature reduces consumption to an ultra-low 2microamp leakage, allowing the pack to be stored for many years with very little battery drain.

Flexible Features

The MAX11080 has 16 selectable overvoltage thresholds, as well as 8 selectable undervoltage thresholds. The undervoltage-detection feature can be disabled if desired. The device includes a programmable detection-delay feature that allows the user to filter out transient events in the battery pack to eliminate false overvoltage or undervoltage alarms. The alarm line operates using a 4kHz heartbeat signal, the absence of which indicates a valid overvoltage or undervoltage event. These features are critical for discriminating between legitimate and false alarms, preventing the application from shutting down unnecessarily.

The MAX11080 is packaged in a 38-pin TSSOP and is fully specified for operation over the -40 degrees Celsius to +105 degrees Celsius temperature range. For more information, please visit: www.maxim-ic.com/MAX11080-Battery.

www.maxim-ic.com

Semiconductors Drive Energy Generation, Conservation and Smart Grid

By David Bell, CEO, Intersil Corporation, Milpitas, California, USA

Semiconductors are unique. They contribute to dramatic improvements in generation, distribution and efficient consumption of energy. Semiconductor manufacturers are in the enviable position of being able to grow their businesses, improve the quality of life for people around the world and slow or even reverse global environmental degradation. Working with system and service providers, the semiconductor industry is making a significant positive impact in addressing the global energy challenge.

Innovative new semiconductor technology is moving us towards a Smart Grid that will level-out power use by running appliances or charging vehicles when surplus power is available, while storing energy for peak demand periods. Newly proposed DC distribution standards can increase the efficiency of factories, buildings, appliances, computers, vehicles, and consumer products.

Existing energy generation uses very basic systems that can be dramatically improved by using new generations of high-performance semiconductors like micro-converters, inverter block FETs, bridge drivers, and battery chargers.

Solar energy systems represent a good example of a system where semiconductor technology adds efficiency. Smart micro-inverters can be embedded in the photovoltaic panels to add control and intelligence, allowing the panels to communicate and

interact efficiently with the Smart Grid. These improvements can be achieved with minimal changes to the physical design of the panel, with many of the benefits realized by simply altering the ways in which solar cells are connected on a solar panel.

There are also opportunities for semiconductor technology in transmission and distribution, where much of the power generated is lost or wasted. Most electrical grids around the world are decades old. These outdated grids are being replaced with "self-healing systems" that are able to diagnose and correct their own problems. These will be enabled by ICs that combine sensing, communication, memory and processing.

This Smart Grid enables decentralized, distributed power generation incorporating renewable sources that builds on the traditional system of wires and transformers. It can monitor specific regional power requirements, control and manage power distribution, and balance loads during periods of peak demand. Intersil is developing the power, monitoring and communications ICs used in these applications, such as solid-state metering devices that deliver remote reading and peak/off-peak rate schedules, and enable grid monitoring and management of fast swing-rate generators.

One of the major issues in front of the electronics community remains the lack of standards governing development and implementation of ICs in the smart grid. These challenges are now being addressed, and over the coming years, ICs will continue to change the way we generate, distribute and consume energy.

Semiconductors add control and intelligence to what are otherwise simple systems today to improve power generation efficiency and enable new and highly desirable cost-saving features in energy conservation. By working with energy producers, distributors, electronics manufacturers and consumers, semiconductor companies are in a unique position to influence a successful global response to the emerging energy and environmental challenges of the twenty-first century.

www.intersil.com

What is the Smart Grid?

By Ash Sharma, Research Director, Power & Energy Group, IMS Research

"Smart Grid" has become a real buzzword within the power electronics press, within the industry as a whole, and even in government circles. However, when asked what the phrase actually means, many industry participants or commentators give fairly vague or even contradictory responses. The difficulty is that there is no fixed definition for this term, so players from different sectors of the industry interpret it in slightly different ways.

So, what is meant by the term smart grid? Some view it as a way of describing a more intelligent method of managing and distributing energy. Others define it as the integration of renewable energy sources into the grid, or the creation of so-called micro-grids. A third group think of the smart grid as an intelligent way to monitor and measure the use of energy inside homes and businesses and dynamically adapt usage to reduce costs.

Recently, the U.S. Department of Energy attempted to define a smart grid as one that has the following seven characteristics.

- Self-heals from power disturbance events
- Enables active participation by consumers in demand response
- Operates resiliently against physical and cyber attack
- Provides power quality for 21st century needs
- Accommodates all generation and storage options
- Enables new products, services, and markets
- Optimizes assets and operating efficiently

Using this definition implies that

smart grid covers a huge range of issues, products and technologies, and really implies that the term "smart grid" refers to an entire overhaul of the electricity generation and distribution industry. Regardless of the lack of industry consensus on what the smart grid really is, it is clear that major changes to the way we generate, distribute and use electricity will occur in the coming decade or two.

Earlier this year, the US Government pledged some $4.5 billion from its economic stimulus plan to promote the development of the smart grid, calling for millions of new smart meters to be deployed nationwide and putting in place a National Coordinator for "Smart Grid Interoperability". North America has always led smart meter deployment, with over 5 million advanced electricity meters installed in 2008 (around 55% of the global total).

According to IMS Research's latest analysis, global smart meter shipments with two-way communications are predicted to grow by 34% per annum on average over the next 3 years, highlighting some of the opportunities that exist. The strong growth in two-way smart meters comes as utilities attempt to provide better information to their customers about their energy consumption and associated cost. This is driven both by legislation and by utilities' desire to reduce peak load consumption.

Home energy usage monitoring will probably not be restricted to just smart meters. GE recently announced that through a partnership with Tendril it may release 'smart' home appliances (e.g. dryers, heaters, dishwashers, air conditioners, etc.) that can communicate with the grid and effectively allow utilities to control when they are switched on and off to manage peak loads. Consumers would sign up to such a service and in return receive discounted energy bills. Whether enough consumers would be attracted to such a deal remains to be seen, and much would depend on the scale of the inconvenience versus the cost benefits to the householder. With around 500 million major appliances shipped every year, and an installed base of many billions, it is little wonder that appliance and component companies are showing keen interest.

It is clear that whatever the precise meaning of the term smart grid, it implies huge change within the electricity generation and distribution industry over the coming decades; change that has not been seen for the last 50 years. This will present massive opportunities across a range of different industries, creating both "winners" and "losers" for the 21st century.

www.imsresearch.com

Frequency Response of Switching Power Supplies – Part 5

Loop gain signal injection size

In this article, Dr. Ridley continues the topic of frequency response measurements for switching power supplies. This fifth article shows how the injected signal size can impact the quality of the measured results, and demonstrates how to optimize the level of injection.

By Dr. Ray Ridley, Ridley Engineering

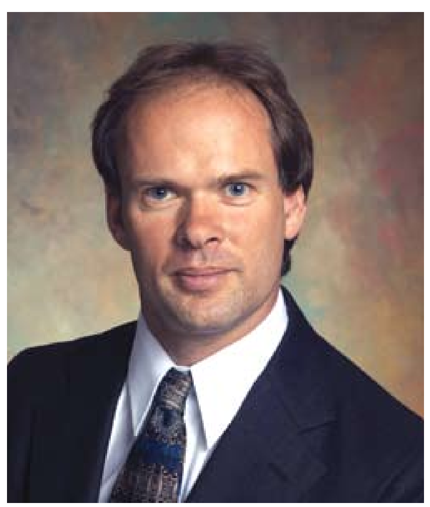
Fixed Loop Gain Injection Signal

Making successful loop gain measurements is a laboratory skill that must be acquired with practice. Very few engineers are taught this skill during their university days, and they must learn for themselves that such measurements are still necessary with switching power supplies, and they must be done carefully in order to obtain trustworthy results.

Once the measurement test setup is properly implemented, as described in the previous article in this series, the right level of signal injection must be used to drive the control loop properly at all frequencies.

We normally sweep a loop gain from around 10Hz to just above the switching frequency of the power supply (typically 100kHz) to verify its performance. Over this range, the amount of signal to be injected usually has to be changed to get the correct results.

Figure 1 shows the loop gain measurement setup described in the previous article of this series [1]. During measurement, it is important to keep



injected signal levels low enough that they only provide a small-signal perturbation to the system, but also large enough that measurements are above the noise floor of the instrument being used. Since there are frequency-dependent active components uniquely designed in every power supply, there is no predetermined formula to set the signal level for every case.

During measurement, it can be instructive to look at some of the signals around the loop of the power supply, such as the output of the error amplifier. However, great care must be taken in doing this. Connecting an oscilloscope probe can introduce noise problems in a high gain and high-noise system such as a switching power supply. Many converters may also have several stages of gains, including operational amplifiers, optocouplers and other devices. All of these must be kept in the small-signal region of operation, and monitoring them all is usually not practical.

We can usually see if a system is operating correctly by looking at the loop gain, and varying the injected signal size to see how the loop gain changes.

Figure 2 shows a measured and predicted loop gain of a power supply with a fixed 10mV injected signal. In the frequency range from 500Hz to 10 kHz, there is close correlation between the measurements and predictions. Below 500Hz, there is not enough signal to resolve the high gain of the system. Above 10kHz, the noise generated by the converter generates spikes in the measurement due to insufficient signal-to-noise.

Figure 3 shows the same system measurement with a fixed 150 mV input signal. The low frequency gain is now much more accurate, down to about 50Hz. At high frequencies, the noise is greatly reduced to the increased injection signal. (For all measurements described here, the analyzer used a fixed bandwidth of 100Hz when measuring the response.)

In figure 4, the signal has been increased further to 1.5V. Now the measurements are accurate down to 10Hz, with low noise. However, at about 500 Hz, there is now a sharp deviation of measurements from the predicted response, and the measurements from here to the ending frequency are very inaccurate.

The system is now being overdriven, and components in the loop are being driven to limits that prevent proper small-signal operation. When a power supply is being overdriven like this, it is usual that the error in measurement begins before the crossover frequency, and continues to the end of the measurement.

Variable Loop Gain Injection Signal

Clearly what is needed for a power supply is an injected signal that changes with frequency. At low frequencies, where the loop gain is high, we want to inject a very large signal. At higher frequencies, the signal must be reduced to prevent overdrive of the circuit. There is no set formula for this – each power supply design has unique power stage characteristics, with unique designs of feedback compensators.

Figure 5 shows the loop gain results with a variable signal injection. At low frequencies, as shown by the green curve, 1.77 Vrms is injected into the system. At high frequencies, the ideal injected signal is about 30mV, a reduction of more than 50 times. From about 200Hz to 2kHz, the signal is reduced between these two values. For most analyzers, this must be done manually during the sweep, but it is automated for the AP Instruments Analyzer [2].

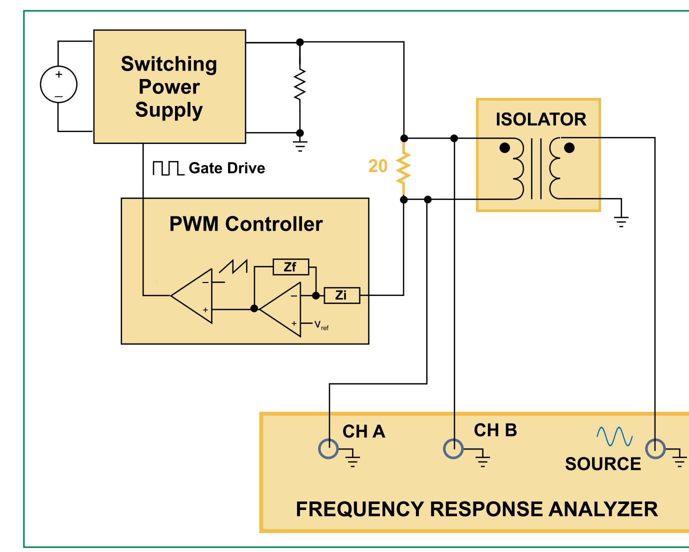


Figure 1: Open Loop Gain Measurement with the Loop Electronically Broken.

Loop Gain Measurements without Predictions

Ideally, we like to plot a measurement of loop gain versus predicted loop gain to show when the measurement is in error. However, many power supplies are very difficult to model and predict, which is one of the reasons why measurements are so important. In this case, we have no reference to tell

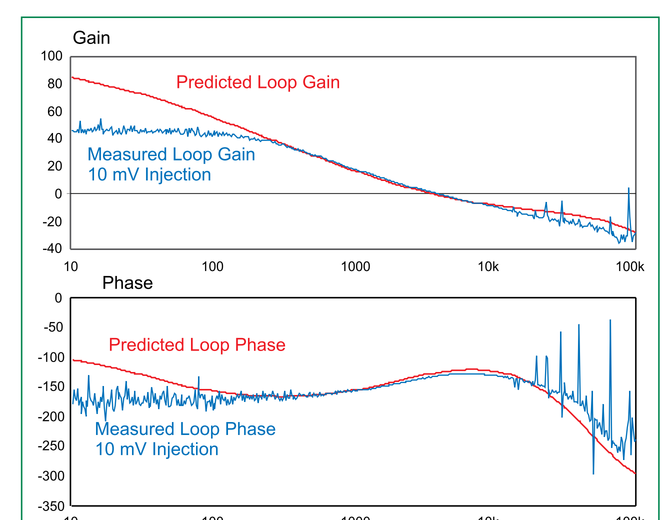


Figure 2: Measurement with 10 mV Injection Signal. Measurement is Noisy, and Limited Gain can be Resolved.

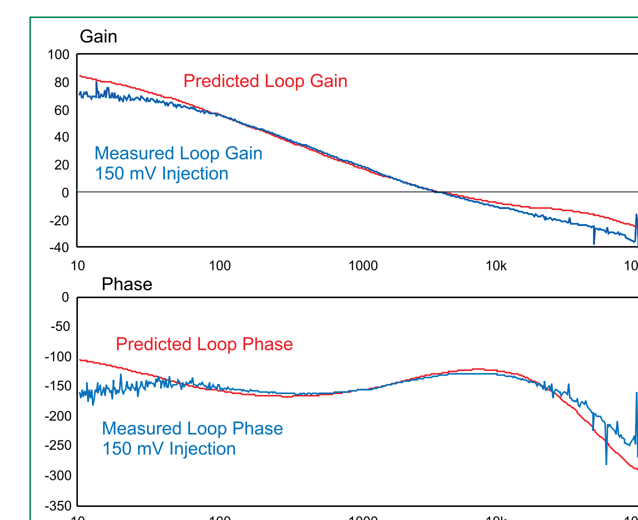


Figure 3: Measurement with 150 mV Injection Signal. Noise is Reduced, and Higher Gain Can Be Resolved.

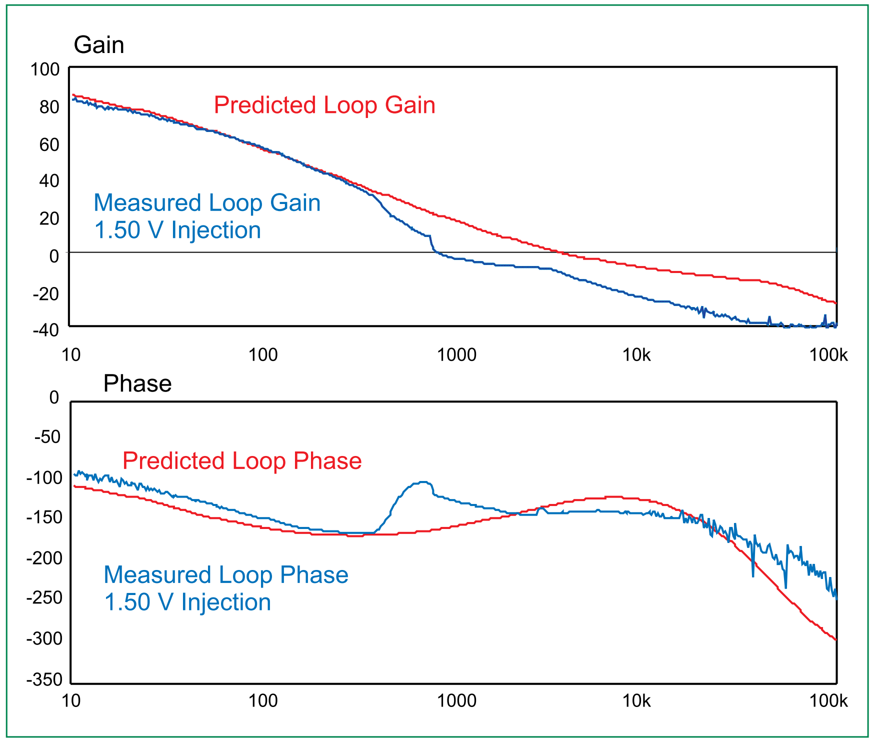


Figure 4: Measurement with 1.50 V Injection Signal. Noise is Reduced Further, Higher Gain Can Be Resolved, but Measurement is Distorted Approaching Crossover Due to Overdrive.

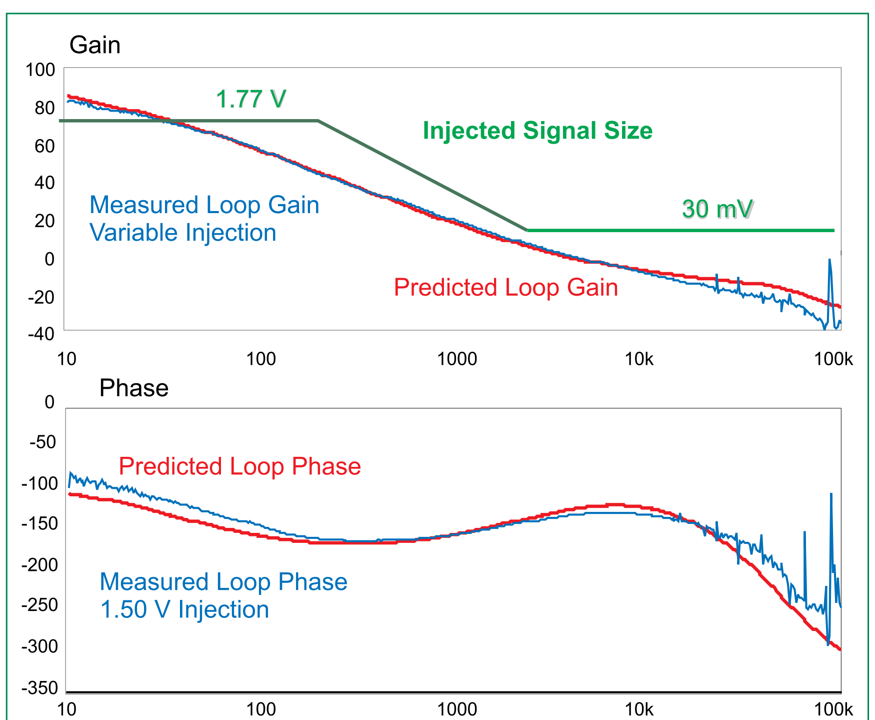


Figure 5: Measurement with Variable Injection Signal. High Signal Levels are Used at Low Frequency, and Reduced Approaching Crossover Frequency to Optimize Measurement.

us when the signal injection is correct.

If you have this situation, the technique is to apply a large signal at low frequencies, and a small signal, perhaps starting at 50mV, at high frequencies. When the loop measurement is valid, you will find that reasonable changes in the injected signal, over a range of perhaps 3:1, will not materially affect the loop measurement. This is the technique that is used to verify the measurement is good – varying the signal injection, and making sure the loop measurement stays constant.

With experience, you will also find that you begin to recognize characteristics that are indications of system overdrive versus actual system response. Loop gain curves tend to be smooth and continuous. Abrupt changes, such as those shown around 1kHz in Figure 4, are unlikely to be the result of a real system response.

Summary

Proper loop gain measurements are a function of proper signal injection. In most cases, the signal must be varied in a repeatable manner to ensure a good result. Too little signal results in too much noise, and too much signal introduces distortions in the measurements and gross inaccuracies. Once this signal level is correct, moderate changes in signal size will not affect the loop gain measurement.

In the next article of this series, the topic of interpreting and specifying loop characteristics will be discussed.

References

1. "Frequency Response of Switching Power Supplies, Parts 1-3", Power Systems Design Magazine, Design Tips Archive. http://www.powersystemsdesign.com

2. "AP Instruments AP300 User Manual", http://www.apinstruments.com/files/Model300.pdf

www.ridleyengineering.com

Intersil and Tower Semiconductor Sign MOU

Next-generation power management platform

I talked with Sagar Pushpala, Senior Vice President, Worldwide Operations and Technology, Intersil, and Russell Ellwanger, CEO, Tower Semiconductor, about the new agreement - and just what it would bring to the power industry. Both companies have achieved outstanding performance in their respective fields. This should be one agreement to watch for developments in the future.

Reported by Cliff Keys, Editor-in-Chief, PSDNA

Intersil Corporation and Tower Semiconductor, Ltd., a leading global specialty foundry, are working together to develop a new high-performance power management specialty process technology platform. A Memorandum of Understanding (MOU) has been signed by the companies to be followed by a formal agreement.

The multi-year agreement combines Tower's technology expertise with Intersil's design and process technology capabilities to provide Intersil with a powerful and innovative platform, accelerating its power management product growth to address next-generation requirements. Intersil will utilize the platform to manufacture its leading-edge power ICs in Tower's state-of-the-art 200mm facility in Migdal Ha'emek, Israel.

Intersil already has an established relationship with Jazz Semiconductor, Tower's wholly owned subsidiary, utilizing previous generation power management platforms. This new collaboration will enable further engineering relationships across a wide set of process technologies that could bring additional business to both companies.

Tower's Bipolar-CMOS-DMOS (BCD) power process offering is highly modular and includes a unique Y-Flash zero mask adder non-volatile memory (NVM) solution which will enable Intersil to boost performance up and keep costs down. Combined with Intersil's power management design and process capabilities, this new process will go beyond its base platform to specifically address the requirements of multiple Intersil product families including digital power, PWM controllers and PMICs.

Sagar Pushpala (left), Senior Vice President Worldwide Operations and Technology, Intersil. Russell Ellwanger (right), CEO, Tower Semiconductor.

"We are very pleased to extend our long-standing partnership to jointly develop a robust and innovative power management platform to address the next-generation needs of power products," said Sagar Pushpala, Senior VP Worldwide Operations and Technology, at Intersil. "Tower provides best-in-class BCD process technology which enables Intersil to offer highly-differentiated power management and non-volatile memory solutions."

When I talked with Sagar, he explained that the relationship with Jazz, now Tower-Jazz has been working successfully for some time. With Intersil's profound richness in IP together with the unique technology of Tower-Jazz, this new collaboration will help Intersil to develop the industry's highest performance power products at competitive costs.

Commenting on the signing of the MOU, Russell Ellwanger, Tower CEO said, "Intersil offers quality, high-performance analog ICs and we are excited that a proven leader in power management has chosen us as their partner and placed their trust in our technology and roadmap to co-develop and manufacture their next-generation power platform. Together, we will enable faster design cycles and cost-effective designs which will be very advantageous for Intersil's customers. We look forward to a fruitful and long-term relationship."

www.intersil.com

www.towersemi.com

www.jazzsemi.com

Breakthrough 2A Solar Battery Charger

Matches peak power tracking with simple control loop

I talked recently with Tony Armstrong, Linear's Director of Product Marketing for the Power Products Group, and Steve Pietkiewicz, Vice President and General Manager of Power Products, about the company's new industry-beating solar power directed monolithic buck battery charger IC for all modern battery chemistries, the LT3652.

Reported by Cliff Keys, Editor-in-Chief, PSDNA

This new innovation, from the company whose business model many others try to emulate, will for sure be a big hit in the fast growing non-utility industries including remote metering, roadside speed and safety warnings, and emergency telephones. Currently, these applications run from a relatively small 600mm x 600mm (25W) solar panel by day and from a battery during the night. The power electronics in many of these existing installations is not optimized for efficiency and is often a discrete solution requiring a tricky set-up and maintenance which increases costs for the manufacturer, operator and therefore, the customer.

With this high-performance yet simple device, the engineer just needs to set it, and then forget it. It's really as easy as that. It copes with all current battery technologies and probably those of the future. Efficiency is consistently over a staggering 95%. There are no complex microcontrollers to fight with; it's all done inside this prime example of engineering elegance at its best. The applications for this device are vast. Although the main ones were mentioned earlier, the list goes on; pedestrian road crossings, navigation buoys, public guidance signage…Steve even told me about a waste crushing machine application which operated throughout the night!

The LT3652 features an innovative input voltage regulation loop, which controls charge current to hold the input voltage at a programmed level. When the LT3652 is connected to a solar panel, the input regulation loop maintains the panel at peak output power. According to Steve, "The LT3652's simple but unique input voltage regulation loop circuitry delivers virtually the same charging efficiency as more complex and expensive Maximum Peak Power Tracking (MPPT) techniques."

The LT3652 accepts a wide range of inputs from 4.95V to 32V with a 40V absolute maximum rating for added system margin. The input voltage regulation loop also allows optimized charging from poorly regulated sources where the input can collapse under overcurrent conditions. It charges a variety of battery pack configurations, including 1 to 3.

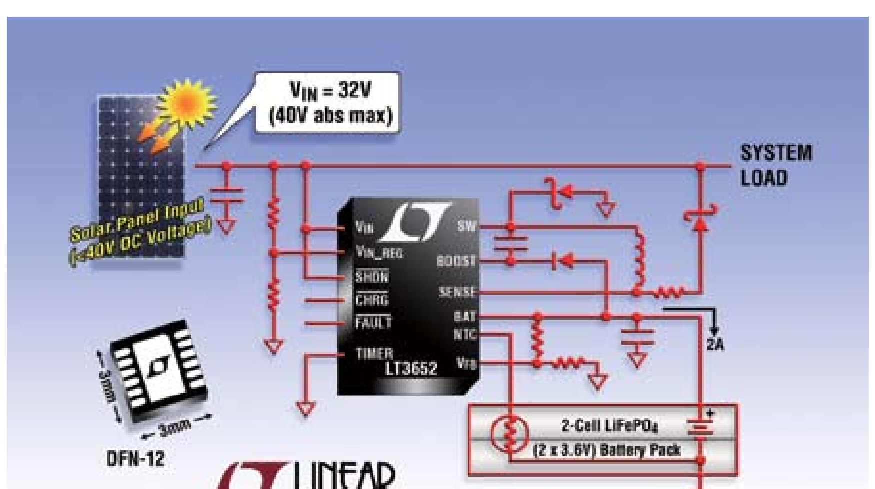


Figure 1: 32V (40V max), 2A Solar Powerable Multi-Chemistry Charger.

Li-Ion / Polymer cells in series, 1 to 4 LiFePO4 (Lithium Iron Phosphate) cells in series and sealed lead acid (SLA) batteries up to 14.4V. Applications include solar powered systems, 12V to 24V automotive equipment and battery chargers.

Input Supply Voltage Regulation

The LT3652 contains a voltage monitor pin that enables programming a minimum operational voltage. Connecting a resistor divider from V_{IN} to the V_{IN_REG} pin enables programming of minimum input supply voltage, typically used to program the peak power voltage for a solar panel. Maximum charge current is reduced when the V_{IN_REG} pin is below the regulation threshold of 2.7V.

If an input supply cannot provide enough power to satisfy the requirements of an LT3652 charger, the supply voltage will collapse. A minimum operating supply voltage can thus be programmed by monitoring the supply through a resistor divider, such that the desired minimum voltage corresponds to 2.7V at the V_{IN_REG} pin. The LT3652 servos the maximum output charge current to maintain the voltage on V_{IN_REG} at or above 2.7V. Programming of the desired minimum voltage is accomplished by connecting a resistor divider as shown in Figure 2.

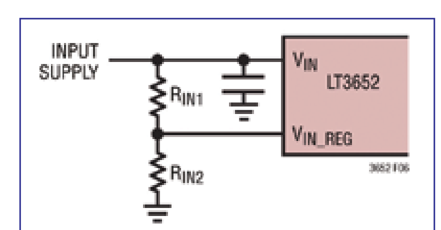


Figure 2: Resistor Divider Sets Minimum V_{IN}.

The ratio of R_{IN1}/R_{IN2} for a desired minimum voltage ($V_{IN(MIN)}$) is:

$$R_{IN1}/R_{IN2} = (V_{IN(MIN)} / 2.7) - 1$$

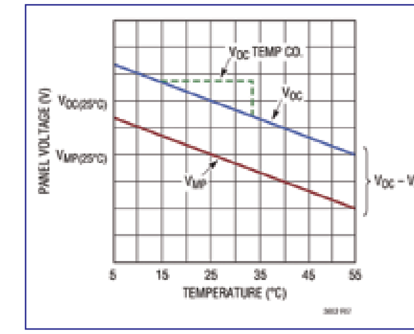


Figure 3: Temperature Characteristics for Solar Panel Output Voltage.

If the voltage regulation feature is not used, connect the V_{IN_REG} pin to V_{IN}.

MPPT Temperature Compensation

A typical solar panel is comprised of a number of series-connected cells, each cell being a forward-biased p-n junction. As such, the open-circuit voltage (V_{OC}) of a solar cell has a temperature coefficient that is similar to a common p-n diode, or about –2mV/°C. The peak power point voltage (VMP) for a crystalline solar panel can be approximated as a fixed voltage below V_{OC}, so the temperature coefficient for the peak power point is similar to that of V_{OC}.

Panel manufacturers typically specify the 25°C values for V_{OC}, VMP, and the temperature coefficient for V_{OC}, making determination of the temperature coefficient for V_{MP} of a typical panel very straightforward.

The LT3652 employs a feedback network to program the V_{IN} input regulation voltage. Manipulation of the network makes for efficient implementation of various temperature compensation schemes for a maximum peak power tracking (MPPT) application. As the temperature characteristic for a typical solar panel V_{MP} voltage is highly linear, a simple solution for tracking that characteristic can be implemented using an LM234 3-terminal temperature sensor. This creates an easily programmable, linear temperature dependent characteristic.

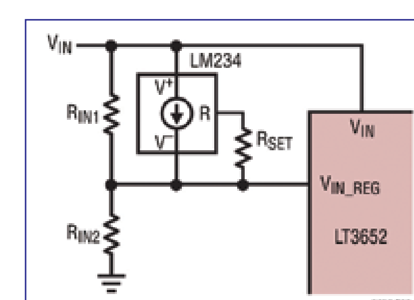


Figure 4: MPPT Temperature Compensation Network.

In the circuit shown in figure 4,

$R_{IN1} = -R_{SET} \bullet (TC \bullet 4405)$, and
$R_{IN2} = R_{IN1}/(\{[V_{MP\ (25°C)} + R_{IN1} \bullet (0.0674/R_{SET})]/V_{IN\_REG}\} - 1)$

Where: TC = temperature coefficient (in V/°C), and $V_{MP\ (25°C)}$ = maximum power voltage at 25°C

With the LT3652's charge current programmable up to 2A, this stand-alone battery charger requires no external microcontroller, and features user-selectable termination, including C/10 or an onboard timer. The device's 1MHz fixed switching frequency enables small solution sizes. Float voltage feedback accuracy is specified at ±0.5%, charge current accuracy is ±5% and C/10 detection accuracy is ±2.5%. Once charging is terminated, the LT3652 automatically enters a low current standby mode, which reduces the input supply current to 85µA. In shutdown, the input bias current is reduced to 15µA. For autonomous charge control, an auto-recharge feature starts a new charging cycle if the battery voltage falls 2.5% below the programmed float voltage.

The LT3652 is available in a low-profile (0.75mm) 12-pin 3mm x 3mm DFN package, and is offered in both E and I grade versions, guaranteed from –40°C to 125°C. Pricing starts at $3.05 and $3.36 each, respectively in 1,000-piece quantities.

www.linear.com

The Power Behind the New Grid

Modernizing today's transmission & distribution system

Grid modernization is inevitable. The emerging smart grid will consist of more than one breakthrough technology, and the benefits of making it a reality extend far beyond the power system itself. Behind the race to define the new smart grid is an emerging set of intuitive, interactive power systems and technologies.

By Tammy Zucco, Strategic Marketing Manager, ABB Smart Grid Operations, and Bill Rose, Communications Manager, ABB Power Systems and Power Products, North America.

Many engineers in the utility power systems industry today are already painfully aware of the need to modernize our existing transmission and distribution system.

Power equipment designed to last 25-30 years has long outlived its lifespan and raised new concerns about energy efficiency, reliability, even blackouts. The power grid as we know it today was never designed to do what we are now asking it to do on a daily basis.

This is especially true in light of today's increasing demand for renewable energies. Most of our power infrastructure was installed long before the restructuring of wholesale electricity markets, and before the proliferation of utility-scale wind and solar farms and other distributed resources.

In the meantime, energy consumption has soared, and while investment in T&D has increased in recent years, it still lags behind the pace of growing demand.

The answer appears to be the much-hyped but often misunderstood "smart grid" (or, "smarter grid").

Essentially, this up-and-coming smart grid equates to the modernization and automation of the entire transmission and distribution system – and all of the power systems and components – from generation to end use.

	Current Grid	Smart Grid
Communications	None or one-way; typically not real-time	Two-way, real-time
Customer interaction	Limited	Extensive
Metering	Electromechanical	Digital (enabling real-time pricing and net metering)
Operation and maintenance	Manual equipment checks, time-based maintenance	Remote monitoring, predictive, condition-based maintenance
Generation	Centralized	Centralized and distributed
Power flow control	Limited	Comprehensive, automated
Reliability	Prone to failures and cascading outages; essentially reactive	Automated, pro-active protection; prevents outages before they start
Restoration following disturbance	Manual	Self-healing
System topology	Radial; generally one-way power flow	Network; multiple power flow pathways

Adapted from Research Reports International

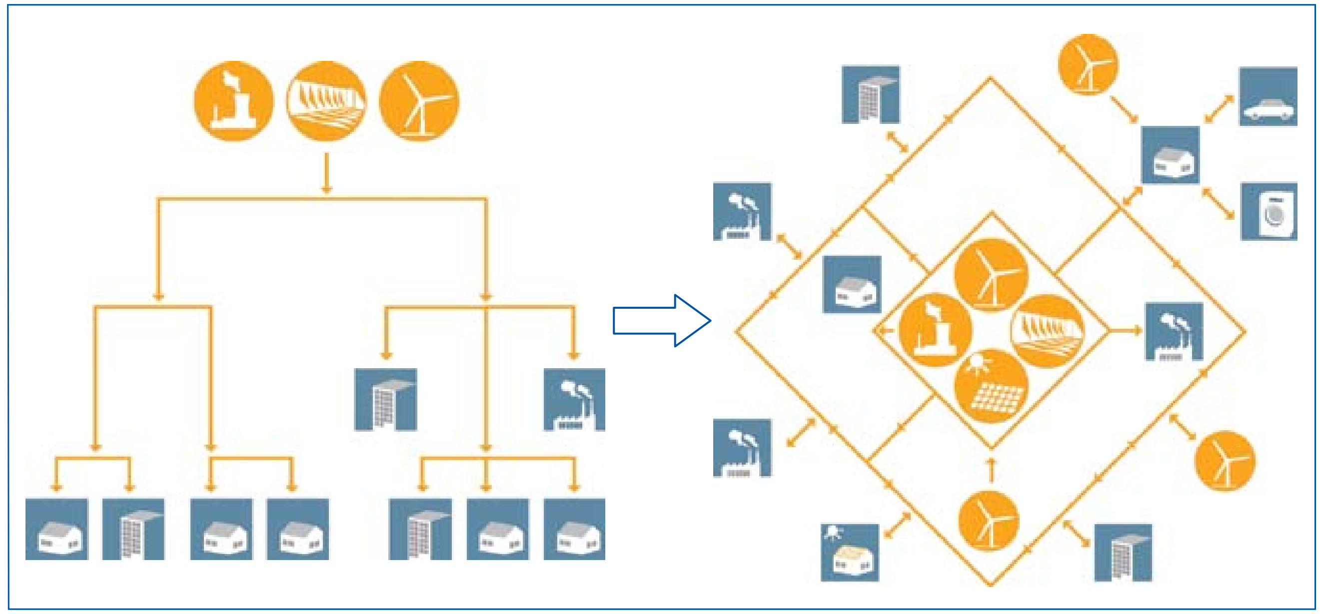


Figure 1: The diagrams above illustrate this shift. On the left, we see today's hierarchical power system, which looks much like an organizational chart with the large generator at the top and consumers at the bottom. The diagram on the right shows a network structure characteristic of the fully realized smart grid.

The mass convergence of many factors – new political momentum, a massive new stimulus package, rising energy consumption, concerns for cyber-security and the environment, the push for alternative energy, and the aging grid itself – has fueled the clamor for a modernized grid.

The result will be a grid that is largely automated across the power system, applying greater intelligence to operate, monitor and even heal itself. The new smart grid will be more flexible, more reliable and better able to serve the needs of a digital economy.

The problem with our existing power grid

Given the level of reliability we are accustomed to both in North America and Europe, it's easy to overlook the unattractive truth that investments in our power system have long been outpaced by the demands we place upon it. While transmission spending, for example, has increased in recent years, it still lags the pace of increasing energy consumption. According to one Morgan Stanley analysis, power outages cost the U.S. economy between $25 and $180 billion every year.

The grid is also not performing at the same level it was decades ago. Energy losses in the transmission and distribution system nearly doubled from five percent in 1970 to 9.5 percent in 2001. There is also a considerable security risk in the design of the grid with centralized generation plants serving distant loads over long transmission lines. However, adding more distributed generation and in particular variable sources like wind

Figure 2: A new modular substation, built by ABB in Colorado for a major U.S. utility. Substation automation using IEC 61850 standards will help utilities better monitor equipment on the new smart grid.

COVER STORY

Figure 3: Wide Area Monitoring Systems (WAMS) and other advanced Network Management functions enable grid operators to proactively detect grid disturbances.

and solar present new operational challenges. It has become apparent that the grid we know today is insufficient to serve us in the future.

Traits that make the power grid "smart"

There is a great deal of variation within the power industry and outside it as to what exactly should be included under the idea of a smart grid. Ask a room full of utility professionals to define the term and you're likely to get a wide range of answers. Similarly, most consumers would likely think of smart meters or home automation, but this is really just the tip of the iceberg.

A fully developed smart grid concept goes far beyond smart meters. It includes technologies at both the transmission and distribution level, and extends to both IT hardware and software such as monitoring and control systems as well as primary equipment like transformers and relays.

ABB defines the smart grid by its capabilities and operational characteristics across the power spectrum, rather than by any one technology. Deployment of smart grid technologies will occur over a long period of time and will add successive layers of functionality and capability onto existing equipment and systems. New technologies are the foundation, but they are only a means to an end. This intelligent grid should be defined by broader characteristics.

ABB's list of smart grid criteria is similar to a recent U.S. Department of Energy list of criteria, though ABB focuses more on broad characteristics rather than specific functions. Under this model, the smart grid is:

- Predictive, in terms of applying operational data to equipment maintenance practices and even identifying potential outages before they occur
- Adaptive, with less reliance on operators, particularly in responding rapidly to changing conditions
- Interactive between customers and markets
- Integrated, in terms of real-time communications and control functions
- Optimized to maximize reliability, availability, efficiency and economic performance
- Secure from cyber-attacks, physical attacks and naturally occurring disruptions

So, how does the smart grid differ from the one we know today? The table below provides a concise summary of some of the differences as they appear in various parts of the power delivery infrastructure.

Figure 4: Today's High Voltage Direct Current (HVDC) for long-distance transmission systems -- and HVDC Light for underground/undersea transmission -- represent a key smart grid technology of the future.

From Hierarchy to Network

Today's power systems are designed to support large generation plants that serve faraway consumers via a transmission and distribution system that is essentially one-way. But tomorrow's grid will need to be a two-way system where power generated by a multitude of small, distributed sources – in addition to large plants – flows across a grid based on a network rather than a hierarchical structure.

Just as the internet has driven media from a one-to-many paradigm to a many-to-many arrangement, so too will the smart grid enable a similar shift in the flow of electricity.

Standards and interoperability

Interoperability – the capacity for devices from various manufacturers to work together – is vital to the realization of a network-based smart grid, and the key to interoperability is standards. Indeed, the entire smart grid proposition is predicated on open communications between the "smart" devices using common protocols. DNP3, for example, is a widely used communications protocol in substation applications and is the de facto standard in North America.

IEC 61850 is an international "open source" alternative to DNP3 and other proprietary protocols that has been adopted rapidly since its introduction. However, for various reasons it has not penetrated the North American market to the same degree as in other parts of the world. Other standards will be integral to smart grid deployments of various kinds.

For example, there is broad agreement that the grid of the future will feature far more distributed generation resources than today's largely centralized system. One standard, IEEE 1547, addresses grid interconnection for distributed resources and the broader adoption of this standard will ease the development of more distributed generation resources.

The U.S. National Institute of Standards and Technology (NIST) has begun a process to identify and propagate key smart grid-related standards within the power industry. In the near term, however, it will be especially important for equipment vendors across the electricity value chain to supply "multi-lingual" devices that can communicate using standardized protocols. Proprietary systems simply do not provide the flexibility required to achieve widespread adoption.

Everyone benefits

The transition to a fully implemented smart grid brings a host of benefits to a wide range of constituencies.

- Grid operators and engineers will enjoy a quantum improvement in monitoring and control capabilities, enabling them to deliver a higher level of system reliability, even in the face of ever-growing demand
- Utilities will experience lower distribution losses, deferred capital expenditures and reduced maintenance costs
- Consumers will gain greater control over their energy costs, including generating their own power, while realizing the benefits of a more reliable energy supply
- The environment will benefit from reductions in peak demand, the proliferation of renewable power sources, and a corresponding reduction in emissions of CO_2 as well as pollutants such as mercury.

Smart grid technologies in use today

Utility companies are already implementing "smart" devices in various ways. Some examples of how smart technologies – and the practices they enable – can impact the operation and overall health of the grid, plus achieve multiple objectives simultaneously, include the following:

- Substation automation (SA) – utilizing international IEC 61850 standards for applications in utilities, industries, solar and wind farms – enables utilities to plan, monitor, and control equipment in a decentralized way, which in turn makes better use of maintenance budgets and boosts reliability. (See Figure 2)
- Real-time situational awareness and analysis of the distribution system can drive improved system operational practices that will in

Figure 5: Emerging smart grid transmission technologies are the key to linking renewable energy sources like solar, wind and water to the power grid and, ultimately, where people live and work.

turn improve reliability

• Fault location and isolation can speed recovery when outages do occur by allowing work crews to drastically narrow the search for a downed line

• Smart Meters allow utility customers to participate in time-of-use pricing programs and have greater control over their energy usage and costs

• SCADA/EMS (Supervisory Control and Data Acquisition/Energy Management System) supervises, controls, optimizes and manages generation and transmission systems

• SCADA/DMS (Distribution Management System) performs the same functions for power distribution networks

• Integrated SCADA/DMS/EMS puts more analysis and control functions in the hands of grid operators

• Wide Area Monitoring Systems (WAMS) collects and analyzes real-time data throughout the power grid – enabling grid operators to detect the first signs of grid instability, prevent the spread of disturbances and avoid grid collapse. (See Figure 3)

• Voltage control through reactive power compensation and the broader application of power electronics increases transmission capacity of existing lines and improves the resiliency of the power system as a whole

• Asset Data Management deals with emerging grid issues such as the aging infrastructure, loss of personnel and expertise, and cost-reduction pressures.

• Distribution Automation for Back-Feed Network Power Restoration provides self-healing in the distribution network through an online method for automated power restoration applications.

• High Voltage Direct Current (HVDC) and HVDC Light systems utilize cable for long-distance transmission systems that are compact and effective, require low maintenance and are environmentally friendly. HVDC Light systems are often used for long-distance underground or undersea transmission. (See Figure 4)

• Energy storage battery applications enable long-term energy storage for use in times of peak demand or natural disruptions

• Flexible AC Transmission Systems (FACTS), a power electronic system of devices, enhances reliability by making transmission lines more resilient and less vulnerable to system disturbances. FACTS also greatly increase the capacity of transmission lines, making them far more efficient.

• Static VAR Compensators (SVC's) are part of the FACTS technology family designs that provide high-speed, grid-voltage support to continue the reliable operation of the electrical grid during electrical disturbances. Installing SVC's minimizes the need to run generation plants in close proximity to system loads, therefore limiting air pollutants and continuing to support the environmental improvement.

Of course this is not an exhaustive list. Smart grid technologies similar to those used for voltage control, for example, are already being applied to bring power from wind farms to the local grid. In this way, the smart grid acts as an enabler for all forms of renewable generation. (See Figure 5)

Status of smart grid developments in the U.S. and Europe

All of these elements, from the economic to the environmental, are amplifying the need for the grid to evolve. We need our power delivery infrastructure to do more, much more than it does today. To meet the many challenges facing it, the grid needs an infusion of intelligence, most of all at the distribution level.

The first steps toward a fully realized smart grid are being taken now, and the potential investment is substantial. EPRI estimates the market for smart grid related projects in the U.S. will be around $13 billion per year over the next twenty years. That comes in addition to an estimated $20 billion per year spent on transmission and distribution projects generally. More recently, a Morgan Stanley report analyzing the smart grid market put current investment at $20 billion per year, increasing to over $100 billion per year by 2030.

Despite these remarkable forecasts, however, smart grid deployments still represent a major departure from current utility practices. For an industry with a time honored focus on reliability and certainty in the application of new technologies, the shift to smart grid presents a daunting challenge. However, some exciting projects are already underway.

ABB is working as part of a consortium in Germany to develop a "minimum emissions region." The MEREGIO project, as it is known, will integrate renewable, distributed generation and provide the grid operator with real-time information on conditions across the grid. This will enable the operator to predict power flow, adapt rapidly to changing situations, send price signals to the consumer to encourage demand or restrain it if there is risk of a bottleneck, and create a regional energy market that incorporates end customers.

Conclusion

The transition from the grid we know today to the grid of tomorrow will be as profound as all of the advances in power systems over the last hundred years, but it will take place in just a fraction of that time. It will require a new level of cooperation between electrical engineers, industry players, the public, and regulatory bodies that have such immediate influence over the direction the process will take. In the end, however, a fully-realized, modernized smart grid will benefit everyone for years to come.

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Power Systems Design NORTH AMERICA

Supplying the Power Grid

Wind Turbine Inverter Technology

The quest for increased reliability

This article describes the common topology of wind power plants with double feed asynchronous generators as well as the requirements of power modules used in the frequency converter systems. The special focus directed towards power semiconductors places a high priority upon durability and reliability.

By Michael Sleven, Technical Marketing for IGBT modules, Infineon Technologies, Germany

The continuously increasing part played by renewable energy in the generation of electricity requires a huge quantity of power semiconductors. Among the most cost effective renewable energy sources are wind power plants. Frequency converters constitute an important part and facilitate the grid compliant power supply. Power semiconductors must meet the requirements of this application with high reliability and build the core of these converters.

Wind turbine with doubly-fed asynchronous generator

The doubly-fed asynchronous (or induction) generator (DFIG) is frequently applied in wind turbine applications.

The DFIG becomes a variable speed system in conjunction with an inverter. In contrast to other systems the generator rotor is not set up as a squirrel cage, but instead is formed as a three-phase winding accessible via slip-rings. An inverter is used to provide both the excitation power as well as the rotating field with variable phase angle. The set-value for the rotor field is determined by the difference of the synchronous rotating field of the mains and the rotor speed. Therefore, the DFIG can be operated both under and over synchronous.

The operating point synchronism means that the rotor speed equals the rotating field of the mains and, hence, the rotor voltage nears zero. This point is usually chosen in the middle of the design range of the wind turbine in order to optimize the efficiency. By controlling the rotor currents in magnitude and phase angle it is possible to provide both a real and a reactive power component. Usually this is achieved by field vector control. To this end the rotor currents are transformed into a Cartesian co-ordinate system. Subsequently this is transformed to a complex number range, which, with the addition of the single line equivalent circuit of the induction machine, provides the torque and flux generating components of the current.

Inverter

Figure 1 depicts the inverter consisting of a grid side converter (NSR), a rotor machine side converter (MSR), as well as a DC-bus. As the flow of energy has to take place both in the direction of the mains as well as the rotor, an uncontrolled B6-bridge is not an option. Both converters are preferably constructed as B6-bridges

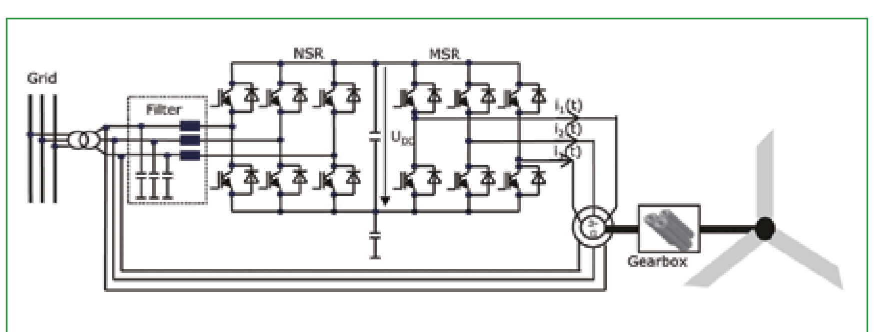

Figure 1: Concept Inverter with DFIG.

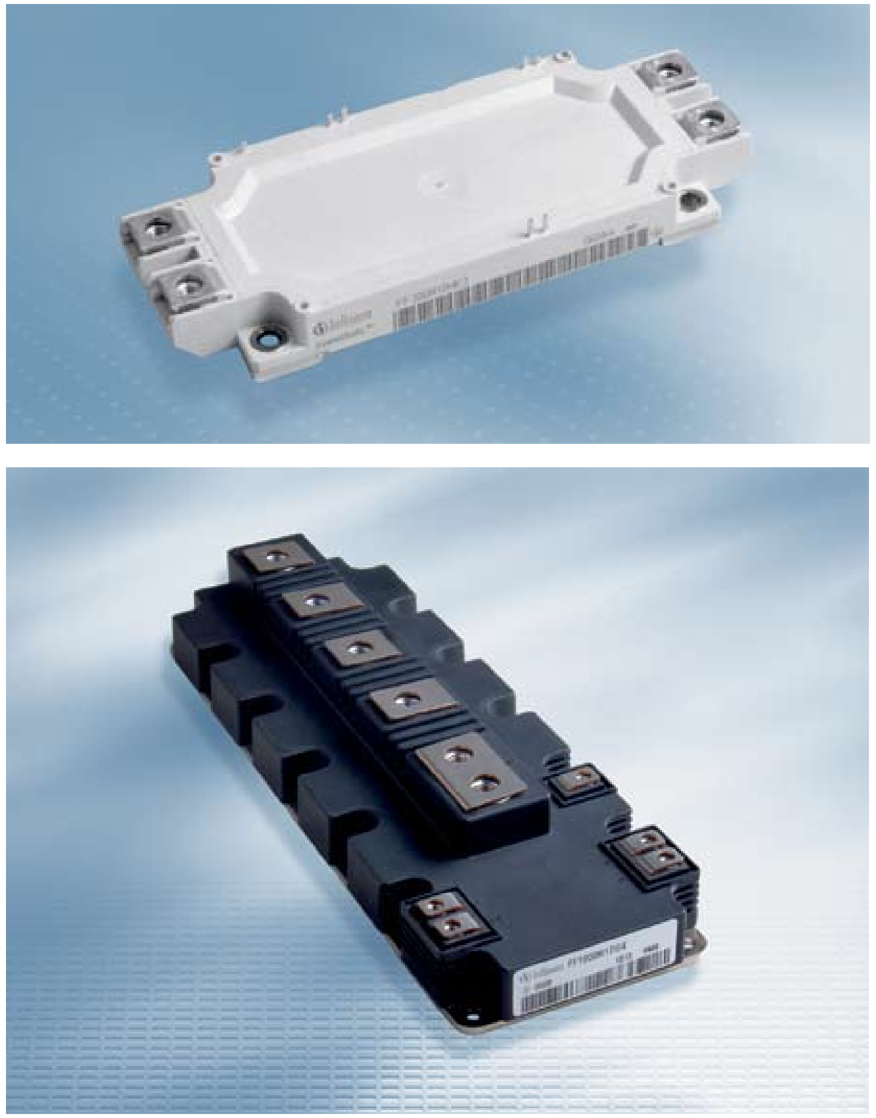

Figure 2: EconoDUAL™ 3 and PrimePACK™ IGBT half-bridge modules.

with modern IGBT modules.

Requirements of the power modules

The loads and requirements of the NSR and the MSR are very different due to large variations of the wind velocity. This results in varying load currents and thus varying thermal load changes of the semiconductors of the two converters. For the operating point synchronism the output frequency of the MSR current nears the value zero. This means that one branch of the converter has to conduct the entire current and the two other branches take half the current each. An equal distribution of losses over all six converter IGBTs does no longer occur now. This condition may last for an undefined period and is therefore to be taken into consideration when designing the converter. The base frequency of the NSR current is between 50Hz and 60Hz, whilst the base frequency of the MSR is in the range of 0-20Hz.

Figure 3: Left, load terminals with ultrasonic weld; right, cross section of a connection between load terminal and ceramic insulator.

This results in a huge number of power cycles in the range of seconds. The temperature swings occur at the junction and the bond wires of the power modules: The differing coefficients of expansion of silicon and aluminium result in micro-movements in the material. This may lead to small cracks in the connection points chip surface and bond wire, up to the so called “Bond Wire Lift Off”.

A so called power cycle curve shows the possible number of cycles confirmed by Infineon at various temperature swings ΔT_j: junction temperature of the semiconductor. The curve applies to the new Fieldstop-Trench IGBT for 1200V and 1700V IGBT modules. This modern semiconductor technology allows the user a switched operation up to a junction temperature of T_{vjop} = 150°C. The user is now able to switch a higher current than with conventional semiconductors with T_{vjop} = 125° C or to increase the power cycling capability fourfold given the same current.

In order to achieve the load cycling capability in the range of seconds, according to the requirements of the DFIG, the surfaces of the semiconductors are metallically covered. This in turn enables a comprehensive optimization of the bond parameters, without damaging the crystalline structure.

Load changes in the range of minutes lead to the other significant damage due to the layer construction with various materials in the module. Caused by this load changes the IGBT module heats right through with a heat differential at the boarders of the various materials. The materials used such as copper, ceramics, silicon and aluminium expand with different coefficients of expansion.

Continual load changes in the range of minutes lead to the fatigue of the solder layer between the copper clad substrate and the base plate. The result is delamination of the solder layer and the increase of the thermal resistance R_{thjc} between the chip and the module case i.e. base plate caused by this. The component fails due to overheating.

The reduction of the substrate solder has lead to an increase of the thermal resistance directly beneath the chip. Thus the semiconductors in the PrimePACK™ IGBT modules are placed in such a way that delamination of the substrate solder will not bear an influence on the thermal resistance directly beneath the chip for a large number of load cycles. In older module generations occasional delamination of the soldered auxiliary and load terminal connections had been conspicuous. In modern IGBT modules for wind turbines these terminals are connected to the copper clad ceramics by ultrasonic welding.

As can be seen in Figure 3, an excellent connection between the welded load terminal and the copper cladding of the DCB exist.

The mentioned improvements for the bond connections, the substrate solder and the connection technology of the terminals have shown a significant increase in the reliability for the employment in wind turbines.

To be able to give an estimate regarding the longevity of the modules in a wind turbine, the correlation between the timeframe of the occurring wind and the consequential variation of the resulting load current and its frequency has to be found.

Requirements for clearance and creepage distances

When wind turbines are erected near the coast and especially off-shore and in environments with very high humidity or increased salt content in the air, flash-overs in the area of the power semiconductors and DC-bus connections occur commonly. Clearance and creepage distances as used in industrial applications are there no longer sufficient, depending on the degree of protection of the switch board cabinet. An increase of the protection degree according to DIN EN 60529 results in a marked increase of system cost. IGBT modules of the PrimePACK™ family with a CTI value > 400 (comparative tracking index), as well as clearance and creepage distances of the housing sufficient for 3.3kV blocking voltage set new standards and constitute a safe solution for fault free operation of the converter in a wind turbine on a long term basis.

www.infineon.com/highpower

Energy Conservation

Hand-in-hand with power supply efficiency

The significant improvements in power supply efficiency that are now becoming possible have the potential to contribute greatly to a reduction not only in terms of energy consumption but also the associated equipment operating costs. However, this in itself is not enough unless peak efficiency points are in line with the load levels to which the supply is subject.

By Conor Quinn, Director of Technical Marketing, Embedded Power, Emerson Network Power and Mick Grahame-Dunn, Business Development Manager, Power Products, Nu Horizons

The direct and indirect costs of fossil fuel usage are proving to be areas of concern for those in high political office as well as to the average member of the public. Diminishing resources are rapidly raising utility bills, while at the same time numerous indicators are now showing the serious long term impact modern society is having on the environment. In many industries this is resulting in a push to deliver systems which are capable of higher efficiency levels, making sure that every Watt of power available is used to its fullest.

One example of where these issues are given a great deal of consideration is in large data center sites. The major players in this sector have set very aggressive roadmaps on how to curb their energy consumption, and expect the technology firms that support them to be able to deliver the hardware to realise this. Worldwide data center electricity consumption has more than doubled over the last eight years, according to research conducted by Stanford University, with over 60 billion kWh being used up in US-based centers alone (equating to 1.5% of the nation's total consumption).

Market Demand & Incentive Programs

Programs such as Energy Star (which was set up by the US Environmental Protection Agency and the US Department of Energy) in North America, and the EU Code of Conduct in Europe are influencing design and purchasing decisions within the power supply industry, thus helping to promote energy-efficient devices and appliances. Guidelines such as these are proving successful in driving efficiency improvements into products and are making lower energy consumption a major differentiator for OEMs. If servers are going to align themselves with the objectives set by the data center firms as well as confirming with international legislation then operating efficiencies need to be improved. It is through advancements both in the design and the application of switch mode power supplies that much of this will be achieved.

Power conversion efficiencies clearly have a part to play, and considerable progress has been made here. While an increase of 10% in efficiency (from say 80% up to 90%) may sound impressive enough, it is even more so when one considers that this actually reduces power dissipation by a staggering 50% (as the wasted power is reduced from 20% of the output power to just 10%). However, overall efficiency is only part of the story.

Emerson's iMP series of configurable AC-DC switcher power supplies.

Greater importance is now being placed on matching system goals and power supply goals. A few years ago, density was the principal driver in the power supply industry and was enabled predominantly through efficiency improvements. The limiting factor in designs of this type would tend to be the power dissipation at full load. Therefore, the power supply efficiency would be designed to be at its peak at the point of highest power dissipation (i.e. full load) and little thought would be put into how it performed elsewhere.

This doesn't always make sense though, as in many applications (including the majority of enterprise and data center servers) the power supplies are configured in a 1+1 configuration to allow redundancy to be built in and guarantee reliable operation. Therefore, under normal conditions, each power supply is running at (or more likely below) half load. As the cost of energy (rather than the space being used up) is now the dominant driver, this dictates that efficiency should be accordingly optimized at (or below) the half load operating point. Considerable improvements have been made at lighter loads. Efficiencies at (or above) the 80% mark are now possible at as little as 10% of the full load. This is an important detail because in many data center applications servers can idle at light loads for very long periods of time. As servers may be disabled or enter standby mode rather than idling at low power in the future, the concept of virtualization can help somewhat in this regard. Considerations of this kind also have the potential to further reduce the overall energy costs.

Enabling New Efficiency Levels

Traditionally, efficiency improvements have been heavily dependent on the continued introduction of lower-loss power semiconductors. Choosing an optimized power topology can also allow better utilization of available semiconductor devices. As packaging becomes more dense, interconnect technologies and functional integration aspects are also key enablers that increase efficiency. For example, a bus-bar may now serve two purposes; in addition to acting as a current distribution element, it can also be utilized as a heat spreader.

A more recently emerged and highly potent enabler to add to this arsenal is that of digital control. While many of the traditional techniques already mentioned allow for efficiency optimization at certain points on the efficiency curve, digital control offers the ability to sense and adjust the operation of the power supply so that efficiency can be dynamically enhanced over the entire load range.

Leveraging High Efficiency Techniques in Configurable Power Supplies

Many of these techniques are now being leveraged across different types of power supplies. For example, the iMP series of configurable AC-DC switcher power supplies from Emerson Network Power also incorporates many of these techniques to boast output power ratings from 600W up to 1500W. The efficiency levels are configuration-dependent and among the highest in the industry for configurable power supplies. Because these applications are not typically redundant, the efficiency is maximised at full load.

These platforms are also full-programmable and the user can configure the power supply to precisely match their application requirements and furthermore make changes later to accommodate any unforeseen alterations to the original spec. All communication between the host controller and the power supply is handled via the I^2C bus, using the industry-standard PMBus protocol. The control software supplied with any iMP device runs under the Windows® operating system on a standard PC, using a highly intuitive, easy-to-use graphical user interface (GUI). The same control screen applies to all modules and all operating parameters. This means that as well as defining a module's output voltage and current, system design engineers will be able to easily adjust its OVP, UVP and OTP limits, change its OCP mode and control signal, and even force fan speed override if needed. The series' configurable power supply control software offers powerful real-time monitoring facilities, with a single screen conveying all the necessary status and performance information at a glance.

Within the product range there is a choice of 25 different output voltages, from 2V to 60V. Single, dual and triple output modules are offered with six different power ratings being supported. There is even an optional power hold-up module to increase voltage sag ride-through time. The series also boasts full medical approval (compliant to EN60601-1 Type B).

It is clear that the purchaser of a power supply should not only consider the purchase price but also the cost of operating the power supply and the system over the life of the product. Failure to consider system efficiencies and energy consumption will only lead to a false economy. Intelligent power supply products, such as the Emerson iMP series, were designed with these considerations in mind. The iMP series, along with other Emerson power supply products (both AC-DC and DC-DC) are available through the Nu Horizons distribution network.

www.powerconversion.com

http://uk.nuhorizons.c

1 MW of Power from the Sun

Solar station eases grid connection of large photovoltaic power plants

Photovoltaic power plants are an expedient addition to wind turbines, because their power curve over a day is similar to that of the the consumers demands. To play a major role in the energy mix, more plants in the megawatt-range are needed.

By Frank Hinrichsen, Development Engineer, FeCon GmbH, Flensburg, Germany

In the last decade the portion of wind generated electricity in some states of northern Germany has reached a level of about 40%. With ongoing growth, grid stability is put at the risk, because power does not arise according to customers demands. To further decrease carbon dioxide emission, new solutions must be found. Solar power plants may be the answer, because their highest output arises when the grid load reaches its climax – at noon.

For years, solar power generation seemed to be a hobby of people who put a few cells on their rooftop. But with guaranteed energy prices (e.g. by the German renewable energy law EEG), falling costs of the photovoltaic modules and, last but not least, increasing efficiency of the inverters, photovoltaic power plants became also a lucrative investment.

If solar energy should play a role in tomorrows energy mix, plants in the megawatt-range are needed. In the past it took much time to plan and install the required cabling, converters and auxiliaries for large plants, because many parallel inverters had to be assembled. Mostly an extra building was erected and air condition had to be taken into account. The parallel inverters had to feed their power to the same grid but each was controlled by its own software without networking. Today things are much easier, because central inverters incorporate most of the equipment in a single housing. Plug-and-play solutions like the Helios Systems 1-MW-Solar-Station HSC1000S (Figure 1) are already available.

All components of the HSC1000S are integrated in a 20ft (6m) high, cube container comprising not only the DC-distribution and the inverter, but also

Figure 1: HSC1000S – the integrated medium voltage transformer can be seen through the opened doors.

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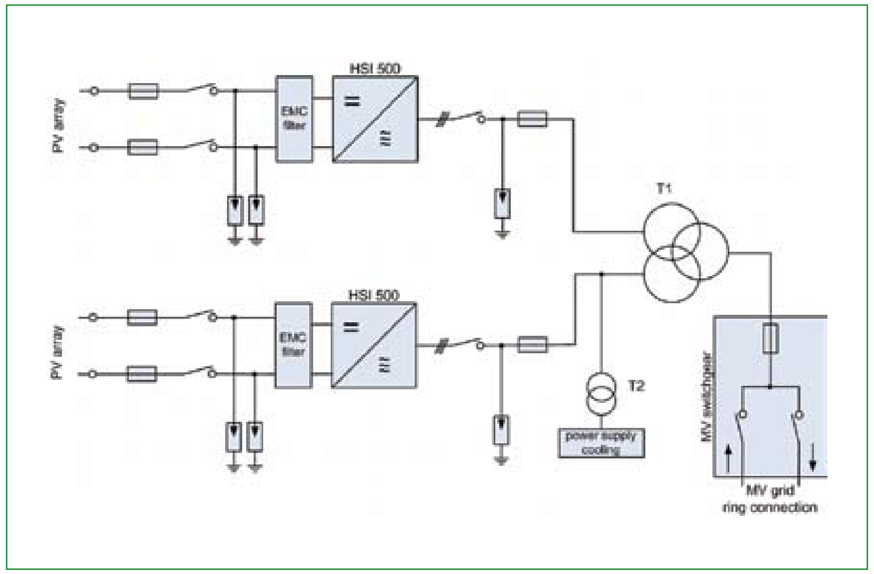

Figure 2: Two 500-kW-inverters (HSI500) are the core of the HSC1000S.

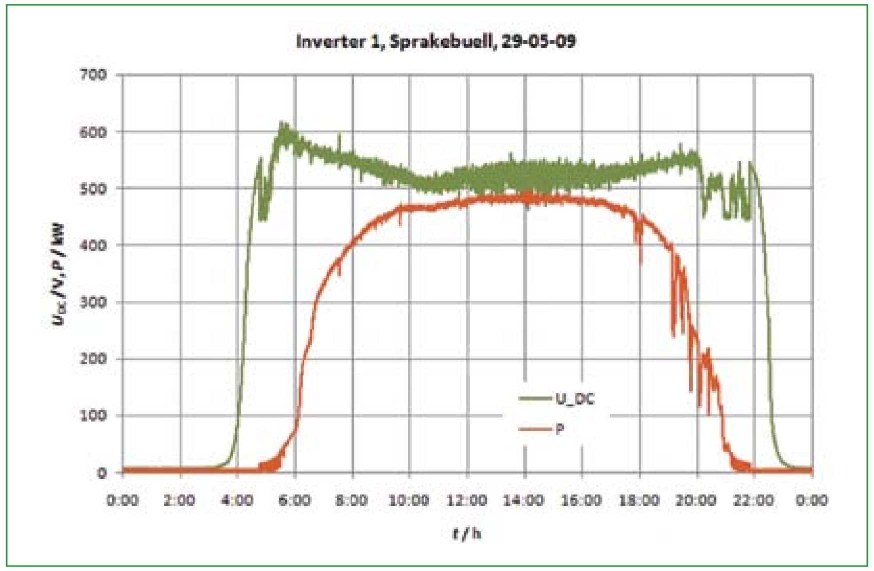

Figure 3: Power output of one HSI500 in Sprakebuell photovoltaic power plant.

a medium voltage transformer and all required medium voltage switchgear to connect the station to the grid. The system is developed and produced in Germany by FeCon and distributed by Helios Systems SL in Spain. It is a completely factory-assembled system – only the DC-connections to the photovoltaic array and the AC-connection to the medium-voltage grid have to be done on site.

As can be seen in Figure 2, the photovoltaic array is linked via fuses, circuit breakers and EMC-filters to the input of the inverter. An overvoltage protection exists for each input line. The current in each string (fuse) can be measured separately for inspection purposes. The inverter system consists of two identical inverters. These inverters operate independently and feed their output power into different low-voltage windings of a special medium voltage transformer T1, optimised for the photovoltaic array. The container can be integrated in a radial or ring-type grid via the internal medium-voltage switchgear. Optionally, the auxiliaries of the inverter system and the heating can be fed by transformer T2 or from an external source.

Each inverter is equipped with all necessary control systems and has its own maximum-power-point tracker. A PC-based monitoring system with an Ethernet interface provides all important information to the operator. It allows visualising temperatures, DC and AC currents and voltages as well as active and reactive output power in form of diagrams and curves. A report of the system status can be retrieved at any time on site or at any other place via the internet. In case of malfunction, a failure message is generated and sent automatically.

Two systems are already installed and have entered normal service in the beginning of this year. One is located in Spain and the other in Sprakebuell, a small village near the German west coast. Figure 3 shows a diagram of the output power of one inverter on a sunny day in May. Nearly 12.5MWh of electrical energy in total were produced on that day. On one hand the intensity of the sunshine is not as high as in Spain; on the other hand, the photovoltaic modules have a better efficiency at lower temperatures, which are caused by a cool wind coming from the sea. The output power of photovoltaic cells falls typically by 4.4% with every 10K, so the rate of yield for photovoltaic power plants in northern Europe is not as low as one could expect.

On the market, a trend to further integration and increasing power density can be observed, so consequently FeCon is planning the next generation of Solar Station with more power in the same volume. Looking ahead, it can be supposed, that plug-and-play inverters are becoming standard for megawatt photovoltaic power plants.

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Power Grid HV Insulators

Electric field calculations are essential

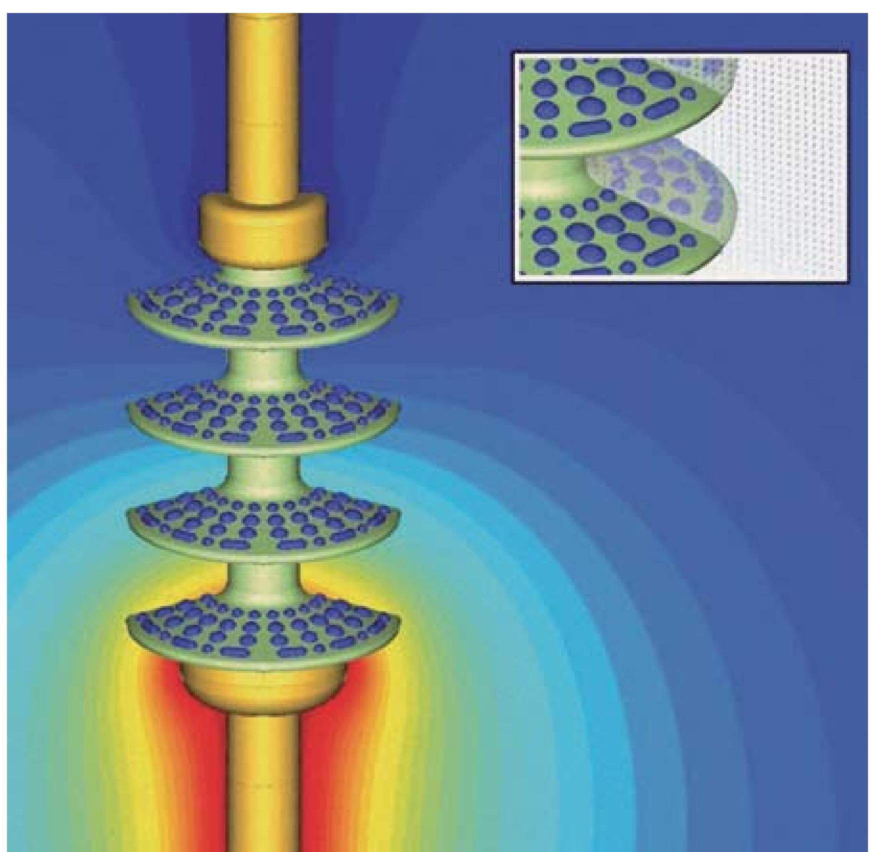
Occurrence of water droplets due to environmental conditions on outdoor high voltage (HV) insulators can lead to localised field enhancement, causing partial discharges and dry arcs which can ultimately result in complete flashover.

By Prathap Basappa, Associate Professor of Electronics Engineering, Department of Engineering, Norfolk State University, Virginia, USA

The reason for this study was to explore the effect of contact angle of water droplets on electrical stress intensification and its implications. Delivering power from a generating station and delivering it to the end customer – whether a consumer or a business- is a complicated process. Ultimately a power grid is as good as its weakest link. A major part of the grid is designing and creating insulators that reduce the likelihood of failure due to flashovers.

These insulators provide isolation between HV power lines and the grounded structures and need to be able to survive the extremities of electrical and mechanical stresses in order to achieve a better longevity. There are two types of insulators present in the market today, Ceramic and Non-Ceramic or Polymer Insulators. Polymer insulators, which were introduced in the 1970's, are increasingly being used due to their characteristics such as better hydrophobicity, light, weight and ease in handling. However, ageing through deterioration is unavoidable since the polymer insulators are made up of organic materials.

When exposed to certain environments, such as pollution, wet conditions, acid rain and ultraviolet radiation, the ageing of the polymer



Analysis of insulator covered with water droplets.

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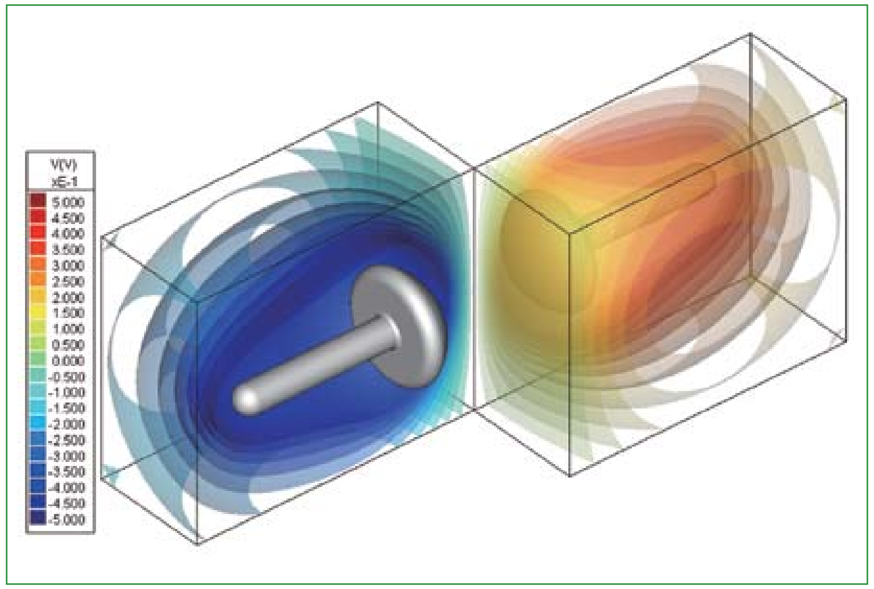

Voltage iso surfaces around mushroom electrodes.

insulator speeds up.

Whilst pollution is of little significance under dry conditions, the presence of water droplets enhances the electric field intensity, which causes the droplets to become deformed and elongate in the direction of the electric field. This results in a shortening of the insulating distance, causing a leakage path on the insulator surface. Development of arcs takes place, and ultimately results in complete flashover. Hydrophobicity is affected by this phenomenon, decreasing the lifetime of the insulator. Even under relatively moderate applied voltages, the enhanced stresses occur at triple points of solid, gas and conductor interfaces and initiates partial discharges. Photons and ions produced by the discharges may lead to secondary electron emission and other discharge processes along the solid and trigger flashover, if the stress is sufficiently large.

To increase the longevity of the insulator a study has been undertaken of the behaviour of water droplets on the insulator in presence of electric field. This was done using a 3D Boundary Element package from INTEGRATED Engineering Software. The COULOMB modelling software is a 3D electric field solver used for applications such as power transmission lines, transformers, insulators, bushings and grounding electrodes. Its calculations include electric field strength, force, torque and capacitance and designers can automatically vary and experiment with geometry, materials and sources.

The team worked on two scenarios. The first was the hydrophobic case where water droplets reside as discrete droplets on Silicon Rubber (SIR). The second case is when water droplets coalesce and form a film due to the diminution of the hydrophobic property. The first set of simulations inquired the role of single, multiple discrete water droplets on the shed and the sheath region in enhancing the E-Field. The second set of simulations looked into effect of the water films on the shed region. A high voltage insulator (138KV) made of SIR is considered to perform the electric field calculations.

In the flashover mechanism, the electric field at the high voltage end, the water drops/films bridging the sheds as well as the shanks play a crucial role. Flashover can occur even if the surface away from the energized end is not fully wetted. The probability of an arc initiating and bridging the insulator is largely governed by the maximum electric stress that occurs on the insulator surface as well as the percentage of the insulator length where the stress exceeds the streamer threshold stress. The presence of a hydrophobic coating (for example: RTV coating) inhibits the formation of water films, leading to formation of discrete water particles which are less dangerous.

Previous studies included simulations using a simple insulator and studying the electric field variations with respect to the water droplet's contact angle, position and the material of the insulator used. The other set of simulations focuses on the behaviour of the water droplets on a practical High Voltage insulator of 138KV and a water droplet of a 900 contact angle is considered. The water droplets were placed on the shed and the sheath regions of the HV insulator and then the number of water droplets was increased to three with the same placing. When the insulator gradually loses the property of hydrophobicity, the contact angle progressively reduces leading to formation of water films instead of droplets. The effect of water films on field intensification was studied by placing water films on the insulator surface. Six cases were considered using a water bubble with a diameter 4mm with a contact angle of 900. The relative dielectric constant of water was taken as 80 and a conductivity of 2.0e-4 mho/meter.

From the results obtained from the simulations the team concluded that the electric field is at the maximum when three water droplets exist on both shed and the sheath regions and it is at minimum when single water droplets exist on the shed region of the insulator. The streamer breakdown voltage is exceeded in all the cases, with half more prone to the occurrence of flashover. The sheath part of the insulator has a narrower dimension when compared to the shed region, which means it experiences a higher amount of stress. On the sheath region, the water droplets will deform into an ellipsoidal shape that leads to greater enhancement of the electric field. Simulation showed that along the sheath, the direction of stress concentration is tangential to insulator surface, explaining why the stress concentration occurs at the triple point between insulator, water and air. In the case of water droplet on the shed the electric field is perpendicular to the shed. Because of this the electric field is enhanced at the top of the drop away from the insulating material comprising the shed. This means that the corona initiation, and subsequent flashover, occurs at the sheath region and the field distribution in the shed region may not significantly affect the conditions. In reality there are often many water droplets on the insulator and each drop would have an effect on the electric field and on each other.

The first set of results show that water droplets in the sheath region greatly contribute towards enhancing the probability of initiation and progression of wet flashover on the insulator surface. The second set of simulations revealed that the electric field intensification is more when there is abatement of hydrophobic property on the SIR insulators when compared to the discrete droplets case. The team concluded that on application of higher voltages the percentage of the length of the insulator, where the field exceeds the streamer threshold, voltage also increases as well as in locations where the voltage spikes (implying locations where the flashover can probably start) occur. Reduction or absence of hydrophobicity leads to formation of water films but when hydrophobicity is increased by RTV coating the possibility of water films forming is drastically reduced. The water films are broken up into discrete particles and, although the voltage spikes are increased in number, the stresses at the initial water droplets end, close to the HV, only exceed the streamer threshold voltages.

Using software for modelling and simulation made all the difference to the work required for this study as it would involve writing several thousands of lines of code, debugging and implementing complex surfaces and interfaces Much of the modelling work was undertaken by students, under the guidance of a junior and senior professor, and they all found the simulation programmes easy to use with good back-up and assistance from INTEGRATED Engineering Software. Apart from its ease of use, one benefit the team found using COULOMB was that they were able to create complicated geometries and obtain usable results in a relatively short amount of time.

In the past, solutions were pure guesswork and the results could never be exact. Now the calculations are done within the software reducing the need to play around with coding. One can concentrate more on analysing the results and producing useful practical conclusions instead of incessantly debugging and creating meaning out of numbers which may not be accurate.

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Accelerating Growth in Solar Power

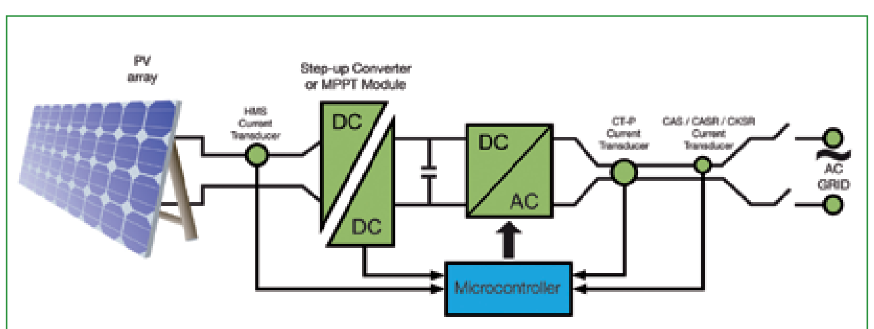
Accurate current measurements are vital

Governments and power utilities worldwide anticipate that a significant proportion of their total energy provision will in future come from photovoltaic (PV) power. But design of the inverters to convert the DC output of the solar cells to grid-synchronized AC, is becoming increasingly demanding. PV inverters must deliver peak efficiency, over a wide range of power levels and operating conditions, while meeting strict safety requirements. The performance of the inverter ultimately rests on precision measurements of basic electrical quantities. Photovoltaic inverter manufacturers need to work closely with transducer manufacturers to ensure that they can continue to support the latest trends in PV technology.

By Stéphane Rollier, LEM Product Manager, Industrial Division, Geneva, Switzerland

The world is demanding that "green" renewable energy sources replace fossil fuels to benefit the environment. Realistic scenarios for electricity-supply systems of the near future include a mix of energy sources, in which solar energy will be deployed on many scales, from large installations covering hectares, to those serving individual households. This has led to a strong growth in the market for photovoltaic (PV) solar inverters. Even with the current economic downturn, the market for PV is expected to reach $34Bn in 2013. A relatively new element in thinking about the PV market is the expectation that grid-connection should be a feature of all scales of installation, with even domestic, single-household systems enabled to feed – and sell – power to the utilities when they generate more than their local load requires.

If PV systems are to realize their potential, they must increase electrical efficiency to reduce the cost-per-kilowatt. It is well-known that the solar-cell-fabricators continue to strive for higher basic efficiencies in conversion of solar radiation into electrical power; PV system manufacturers are also designing next-generation inverters that deliver more power, and offer higher efficiency as well as increased intelligence and functionality by adding diagnostic and other capabilities. One of the latest developments is multi-stringing: this maximizes energy yield by connecting several strings of series-



Typical connection of PV array to the grid.

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connected solar cells, each with its own maximum power-point tracking (MPPT), to a single inverter. The solar cell is not an easy power source to work with. Open-circuit, it develops a nominal voltage of around 0.6V: commonly, there would be up to 72 cells in a solar panel yielding up to 44V open-circuit. Short-circuited, the cell will deliver a certain level of current. The cell will deliver maximum power at a certain voltage and current, at a point between these extremes. This maximum power point changes with changing operating conditions (such as incident solar radiation level) making it necessary for the inverter to track it in order to maintain peak efficiency. Designers achieve this with a software algorithm, relying on voltage and current transducers for instantaneous data collection.

The inverter output current, typically 15 to 50A (RMS), flowing to the grid is measured by a transducer for feedback to the controller for pulse width modulation (PWM) sine wave control. Controllers are mainly based on microprocessors or digital signal processors supplied with +5V and working with voltage references shared with other active components of the electronic control system.
LEM's HMS current transducers operate from a +5V power supply. Their internal reference voltage (2.5 V) is provided on a separate pin, allowing them to be used easily with DSPs or microcontrollers. But, they can also accept an external reference (between 1.5 and 2.8 V) from these same DSPs, from which they then derive their own reference. This makes the overall application more efficient, facilitating reference drift cancellation in the error calculation.

Inverters employed in solar panels connect to the grid either via a transformer, or use a direct-connection, transformer-less design. The former may, depending on topology, use a mains-frequency transformer at the point of connection to the grid, or it may use a high-frequency transformer as the point-of-isolation within the inverter circuitry. A low frequency transformer-based circuit offers inherent protection against the injection of DC into the AC grid, but has an efficiency penalty due to the losses in the transformer itself. The AC output of the inverter might have a DC component due to, for example, lack of precision in IGBT commutation; a DC offset in the current transducer used in the control loop of the inverter would manifest itself as a DC component in the output, thus any offset should be as low as possible. Very strict limits are imposed on the acceptable levels of DC supplied to the grid; not the least of the designers' problems is that these limits vary from country to country, sometimes expressed as a percentage of nominal current (0.5%, for example), sometimes as an absolute limit that might be as low as 20 mA (UK standard). In all cases, there is the need to measure very small DC currents in the presence of large AC currents, with minimal offset and drift.

LEM's CT transducer range.

A further safety issue is earth leakage control. In a transformerless configuration a path to ground will in any case exist through the leakage capacitance of solar panel or the human body impedance. There is a need to incorporate a Residual Current Device (RCD) to detect unsafe current flowing to ground – or, to incorporate the function of an RCD into the inverter design, once again by use of appropriately-specified current transducers. Using that approach allows the system to trip at the generally-accepted different safety levels defined by standards (few mA) (AC and DC) while accepting a larger stationary AC ground current that arises due to capacitance between the solar cell installation and a ground plane in its vicinity.

LEM designed the CT transducer range specifically to meet the needs of modern solar-inverter topologies for a compact, low-cost and reliable earth-current-detection solution based on a current transducer. They are differential current devices with nominal ranges of 100mA, 200mA and 400mA, providing a linear voltage output of 5V at nominal current. Response time is better than 20ms at 80% and 60ms at 90% of nominal current. The use of a high technology ("fluxgate") design is key, especially to achieve the accurate measurement of very small DC or AC currents with low offset drift; DC and AC components up to 18 kHz can be measured.

The CT products are PCB mountable, small size, lightweight components with an aperture for insertion of phase wires. The same, closed-loop-fluxgate technology is employed in the PCB-mounted CAS/CASR/CKSR current transducers; for AC and DC isolated current measurement, they cover 6 to 50A (RMS) nominal, handling up to three times the nominal values for the peak measurement and up to 300kHz (+/-3dB). They were specifically designed to match the latest trends in inverter design, requiring improved performance in areas such as common-mode influence, thermal drifts (both offset and gain; maximum thermal offset drift is 7 to 30ppm/K depending on model), response time (less than 0.3 microseconds), levels of insulation, +5V power supply and compact size.

Special control is required at the output of the inverter, in order to provide synchronization with the grid. The inverter must shape the sinusoidal AC current so that harmonics are minimized and react quickly to changes in the grid-side current. The transducers used here must provide very fast response times combined with low offset drift. Minimizing offset drift due to changes in temperature also helps to minimize the need for complex compensation algorithms. Conversely, at the DC input of the inverter where a transducer monitors the MPPT, the rate of current variations is relatively slow, allowing the use of a low-cost open-loop transducer.

Inverters that operate without a grid connection – for example, charging batteries for stand-alone systems – are free from the restrictions enforced by utilities, but must nevertheless meet many of the same demands for safety and efficiency.

It is likely that the specifications that PV-inverter designers must meet will become even more demanding. For example, as well as limiting DC injected into the grid supply, some consensus may emerge on allowable levels of total harmonic content of the inverter output current; at present a variety of local limits apply depending on geography. This imposes the need to precisely measure currents at frequencies much higher than the 50 or 60Hz of the grid.

Close collaboration between transducer manufacturers, such as LEM, and PV inverter manufacturers will provide the basis for developing technologies which, together, can deliver real competitive advantage and market share within the growing solar sector.

www.lem.com

Smart Grid Intelligence

Efficient power supply solutions for smart metering

The new 'smart grid' concept is rapidly gaining favor with electricity suppliers worldwide. Faced with a growing need to utilize infrastructure more efficiently while reducing greenhouse gas emissions, utilities are using the smart grid to intelligently control and monitor the distribution and consumption of electricity. Suppliers expect this implementation to result in a dramatic savings in energy consumption and more efficient use of generating capacity.

By Silvestro Fimiani, Product Marketing Manager, Power Integrations, Inc., San Jose

The aim of the smart grid is to even out electricity consumption throughout the day and reduce peak loading by changing user behavior through variable charging schemes or by directly controlling the consumer's equipment. By leveling out the network load, utilities can more efficiently manage their generating and transmission capacity, reducing emissions and avoiding power outages.

A core element of the smart grid is the smart power meter. Much more than a standard (dumb) power meter, the smart power meter communicates with both the energy supplier and the consumer to provide real-time information on energy consumption and cost. Smart meters allow the utility to implement a variety of control and incentive programs (e.g., real-time variable pricing based on peak network loading). With features such as in-home energy displays or "eco-panels," the consumer can be warned when a peak loading rate is being charged. The consumer can then make an informed choice to postpone the use of heavy consumption appliances such as washers or dryers until a lower rate for electricity is available.

The smart meter is envisioned to be at the center of a home information network, gathering data from smart appliances and communicating with the energy supplier (see Figure 1). The communication handling and security features in smart meters must be both flexible and upgradeable. Power management within the meter and achieving maximum power efficiency are of prime importance. The power supply must work over a wide dynamic range with fast response to changing demands when transmitting data or fulfilling other functions. This requires careful power circuit design.

The technical requirements for a smart meter power supply can vary, but there are some requirements that are highly desirable for all applications. These include current limiting, thermal shutdown, automatic fault recovery, reduced electromagnetic interference (EMI), high efficiency, and very low standby power consumption. These requirements predicate the use of a switch-mode power supply, even for very low consumption applications. Power Integrations (PI) is one manufacturer offering a range of SMPS controllers suitable for smart metering. The controllers all include a 700-volt power MOSFET combined with comprehensive control and protection circuitry on a single chip.

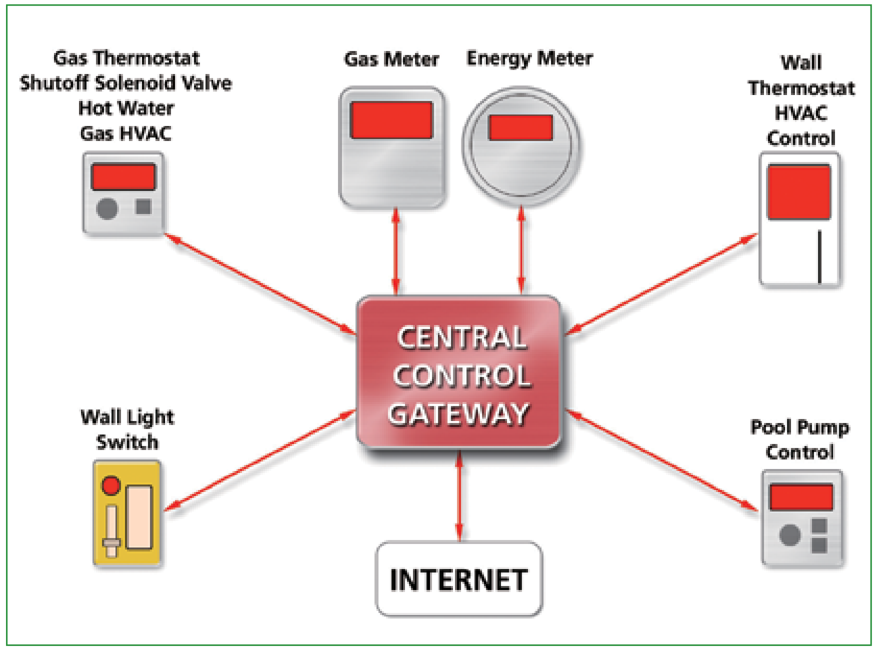

Figure 1: The smart home automation network.

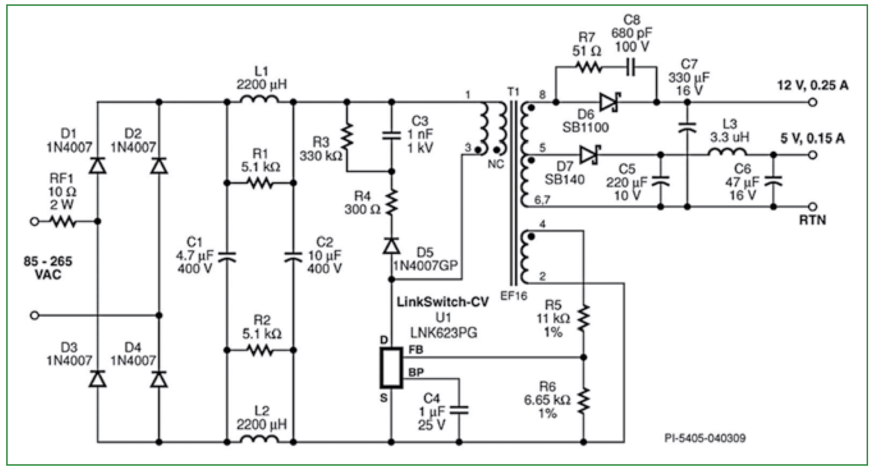

Figure 2: Schematic of 3.8 W dual-output power supply using LNK623PG.

For a given application, several different products could be used, but one would generally lend itself better due to its specific characteristics. PI has developed several utility meter applications using both its *LinkSwitch*® and *TinySwitch*® product families.

For the designer, there are several choices to consider. The majority of applications will call for an isolated supply, in which case a flyback converter would be employed, but for a lower cost, non-isolated design, a buck converter using *LinkSwitch-TN* could be implemented. For tight voltage regulation (±2%) an opto-isolator would be required in the flyback control loop. A clampless design could be implemented with the *LinkSwitch-XT* which provides both a ±2% CV and ±5% CC characteristic. If ±5% voltage regulation is acceptable, then a substantial saving in component count can be achieved in a design employing primary-side regulation with no optocoupler required. For this, the *LinkSwitch-CV* would be suitable for power outputs from below 1 W up to 8.5W. For higher power levels up to 28W, the *TinySwitch* family could be employed.

A typical requirement for a smart meter power supply would be to deliver 5 V and 12 V multiple outputs from a universal 85 to 265 VAC with efficiency meeting California Energy Commission (CEC) / ENERGY STAR® EPS v2 and conducted EMI meeting CISPR22B / EN55022B. Figure 2 shows an example of a power supply meeting these requirements.

This circuit employs a *LinkSwitch-CV* switch-mode controller (U1) in a primary side control flyback circuit . Protection features provided by this circuit include auto restart for control loop open/short faults and output open circuit conditions, and hysteretic thermal shutdown. An extended creepage distance between high- and low-voltage pins on the package prevents arcing in humid environments. This is important for metering applications where the equipment is often situated in uncontrolled conditions.

In the primary side of the flyback circuit, the 700 V MOSFET in U1 switches the primary current through winding 1 3 of T1. An RCD-R clamp (D5, R3, R4, and C3) limits the leakage inductance drain voltage spike. U1 employs a unique ON/OFF control scheme to provide constant voltage (CV) regulation of the output characteristic. Primary-side control is achieved with the output being sensed by a feedback winding on the transformer and applied to the FB pin of U1. The switching of U1 is controlled in response to the current into the FB pin. In this way, an effective closed-loop control of output voltage is achieved without the need for any secondary-side control or optocoupler. The pi (π) filter (L1, L2, C1 and C2) minimizes conducted differential mode EMI; the circuit is rugged to surges and designed to meet IEC950 and UL1950 Class II safety requirements.

Despite the very low component count, a regulation of ±5% on the 5 V output and ±10% on the 12 V output is achieved across the full input voltage and load range.

The installation of smart meters and their employment in smart grids is accelerating. Their use can make a significant contribution to the more efficient distribution and utilization of energy in the future. With the large number of smart meters that are anticipated to be installed worldwide over the coming decades, every economy in materials use and power consumption will help to maximize their effectiveness and accelerate their adoption. The utility meter power supply designs developed by PI provide an efficient foundation for all metering applications.

For more information on smart grid metering, please visit the Power Integrations microsite

www.powerint.com/smart-grid-metering

Energy Saving In Induction Machines

Two-zone transformerless soft-starter

In order to save energy in applications using induction machines, a non-standard approach to a soft start of induction motors has been considered to improve the quality of a starting current of the motor and to reduce -or even remove- additional consumption of reactive power in a network. This approach uses a symbiosis of concepts of discrete peak and continuous phase regulation of voltage.

By Zinoviev G.S., Udovichenko A.V., Department of Industrial Electronics, Novosibirsk State Technical University, Novosibirsk, Russia

It is well known that upon starting, induction motors - especially the high-voltage varieties – a heavy starting current is generated, which leads to pronounced sags in the voltage of supplying network. It is therefore of importance to develop energy-saving devices that limit the starting current and ensure a soft start-up of the motor. Thyristor devices commonly used to soft start alternating-voltage motors, reduce the starting current by a factor of 2-3, but deteriorate its waveform substantially and produce an additional reactive component of the current caused by phase regulation of the voltage due to the delay angle of switching of the thyristors. As a result, the input power factor decreases and losses of the motor's active power increase. The latter can lead to the failure of a motor during slow starting due to thermal overload.

In this article is proposed a non-standard method for designing soft-starting devices for asynchronous motors which enables the improvement of the quality of the starting current and to reduce or even eliminate additional consumption of reactive network power. This method is based on symbiosis of the concepts of discrete amplitude and continuous phase regulation. As a result, not only is consumption of reactive network power reduced but also the input-current form and quality of the output voltage are also improved. This is made possible with the use of an input voltage capacitor divider.

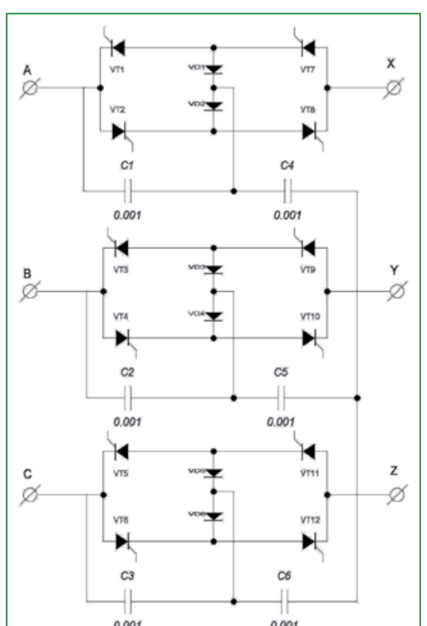

Figure 1: Schematic diagram of three-phase two-zone thyristor regulator.

Two-zone thyristor regulator of an alternating voltage

At present, all industrial thyristor regulators for alternating voltage are based on the classical scheme comprising opposed-parallel connected thyristors. Depending on the magnitude of the regulator input voltage (0.4-10kV), the thyristor group comprises 1-5 series-connected thyristors. The basic parameters of the one-zone alternating-voltage regulator can be improved in schemes with zone regulation of the output-voltage amplitude. Usually multizone regulation of an output voltage is achieved by use of a transformer with taps to which are connected opposed-parallel groups of thyristors. The drawbacks of this regulator are the high relative voltages on the thyristors, the large number of zones, and the necessity to use a transformer.

The scheme offered by a multizone regulator on an example two-zone is shown on fig.1

Figure 2 shows schematic diagrams of three-phase two-zone thyristor regulator with A, B and C input plugs and X, Y and Z output plugs. Clamping (cutting) diodes provide fixing a voltage on thyristors. A capacitor divider provides half voltage of the network, which is used to obtain two levels of the input voltage of the regulator and hence, two regulation zones of the output voltage. In contrast to the classical thyristor regulator, the thyristors with additional fixing diodes are arranged as subsequent opposed-parallel connected chains. In general case, it is possible to obtain 1/n part of network voltage for all semiconductor devices (here n=2), which reduces costs of thyristors compared to the classical regulator.

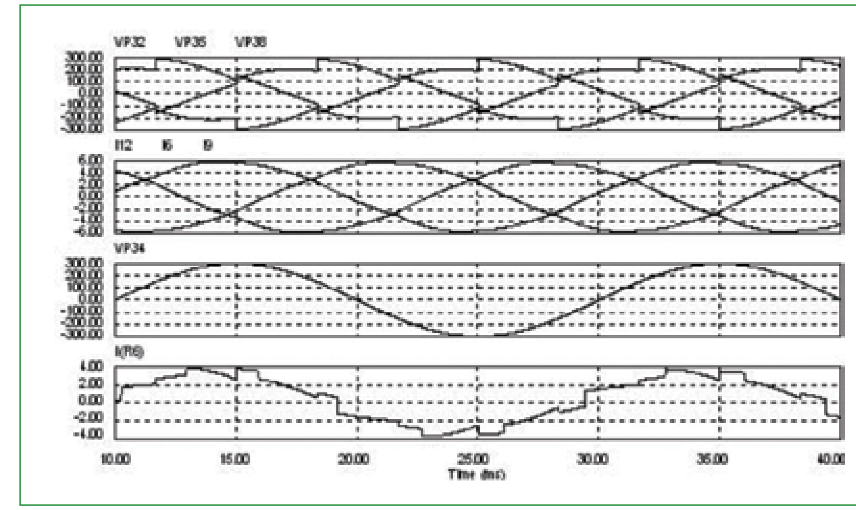

Figure 2: Modeling results for three-phase two-zone regulator.

This advantage, however, is paid for by a current flowing in the upper regulation zone through two thyristors connected in series rather than through single thyristor as in the known scheme. But since we use a chain of several thyristors connected in series rather than a single high-voltage thyristor in the classical regulator, the total loss at the thyristors of the regulator proposed are expected to be even smaller for the existing classes of thyristors.

In a similar manner, one can construct n-zone alternating-voltage thyristor regulators and rectifiers using an n-zone voltage capacitor divider.

Figure 2 shows the modeling results obtained by the PSIM program for three-phase, two-zone regulators. The output voltage vs. current and input voltage vs. current in the second (upper) regulation zone, are shown.

Figure 3 shows the load (external) characteristics of the three-zone voltage regulator. For the upper regulation zone, the characteristics are reasonably stiff up to loading currents exceeding the capacitor-divider current by a factor of 2-4.

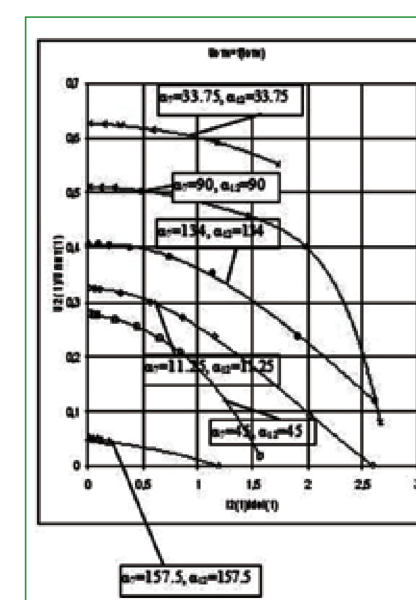

Figure 3: The external characteristics of the three-zone voltage regulator.

At a power factor of induction machine of 0.85-0.92, the current of a capacitor divider practically completely compensates the reactive component of a current of the machine. As a result, the input power factor of a regulator will be practically equal to unity, and RMS value of an input current of the regulator will be less than the RMS value of a current in the machine.

It will reduce losses of active power from a current of a regulator in a power line. To estimate the quality of the regulator output voltage, we use its harmonics coefficient and integral coefficient of voltage harmonics. The quality is improved by 30-40% compared to one-zone regulation. It follows that overheating of the motor can be avoided upon start-up of the motor.

Conclusions

1) An analysis of the energy characteristics of the two-zone thyristor regulator proposed shows that the quality of the output current is improved substantially, which ensures soft start-up of the motor. Simultaneously, the quality of the input current improves; we have a "green power" device to provide energy-savings.

2) Multi-zone regulators of alternative voltage proposed provide time controllable soft start-up of powerful high-voltage induction motors with specified quality of the current. These motors are widely used in city systems of communal heat and water supply and also in mining and metallurgical electrical equipment.

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Intelligent Energy Measurement

Current transformers for "Smart Meters"

Let's consider the public perspective: "Intelligent meters locate electricity hogs"; "Intelligent current meters"; "How smart is the power customer?"; "The digital electricity meter gains broad acceptance". These are only a few of the press headlines from recent months - under which one could than read more and more analyses and estimates on energy meters. The development of electronic meters is driven by the necessity to act in an eco-conscious manner and save energy.

By Dr. Ulrich Cebulla, GF-S Special Projects, Vacuumschmelze, Hanau, Germany

The European Union initiated the climate-control package "20-20-20" in 2007 – with the aim of reducing the output of greenhouse gases by the year 2020 to the extent of 20%, to increase energy efficiency by 20% and raise the percentage of renewable energy sources by 20%. For the electric-power market, this means that to achieve this aim, energy consumption must be calculated as accurately as possible. For this purpose, new electronic meters – so-called "Smart Meters" - are needed.

Figure 1: Exterior view of a "Smart Meter". The transducers are in the lower section; the display unit can be seen in the upper section.

For several years now, the engineering of these "Smart Meters" has been under way on a global scale. In this context, the United States is the forerunner; yet also in many European countries, the old meters are being replaced by "Smart Meters".

Current transformers (CT) made of nano-crystalline or amorphic magnetically soft cores such as those manufactured by the company Vacuumschmelze GmbH & Co. KG in Hanau are important components of this process when it comes to measuring current. These current transformers demonstrate particular suitability for the exact and reliable calculation of energy consumption.

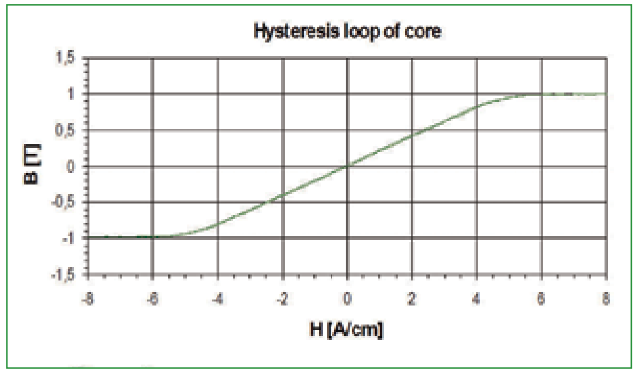

Figure 2: Hysteresis response of a current transformer with a homogenous core. Due to the highly linear characteristic curve around the operating point at H = 0, the very good response with regard to the DC stability and freedom from distortion for the output signal occurs.

Intelligent meters squeeze old meters out of the market

Each household has at least one energy meter which measures the electrical energy consumed – in kWh (kilowatt hours). In Germany, this is usually an old Ferraris meter (an electro-mechanical meter with an aluminium platform and a mechanical roller counter. In this context, it is still standard procedure to record energy consumption annually and to pass it to account via monthly advance payments. Yet the times are changing: energy costs are continuously on the rise – and suppliers as well as consumers have an interest in establishing the most effective and most affordable energy-supply system possible. Climate-control policy also demands of all parties involved the intelligent and eco-friendly handling of resources.

Now, newly-passed energy legislation in Europe is forcing the energy companies to introduce (as of 2010) new, intelligent meters.

Already in the past few years, in this context, where the gauging of the consumption of electrical energy is concerned, new electronic meters (so-called "Smart Meters") were tested by energy companies.

These devices – unlike the old Ferraris meters – enable the calculation of consumption in virtually real time, along with the supply of this information to the consumer via various communications channels (for instance, via WLAN or power-line communications) – also to one's home computer. This means that each household which has installed such a new meter can individually calculated the current rate of consumption, monitor consumption habits and with that, for instance, identify 'energy hogs' within the household.

This measures must be flanked by new rate models from energy companies - which would then enable consumers to act even more cost-consciously (for instance, by introducing load-variable rates or rates dependent on the time of day.

With that, the old meters have become obsolete and are being rapidly replaced by the new electronic meters.

Electrical-energy consumption: Germany as an exemplary model

In Germany, there are approx. 39 million households. Their energy consumption by way of electricity amounts to approx. 146 million kilowatt hours per year – which corresponds to approx. one quarter of total consumption of electrical energy in Germany.

Currently, the total costs for electrical energy (for a typical four-person household in Germany) amount to 600 € - 1,000 € per year.

Economic research assumes that solely due to the comprehensive introduction of intelligent energy meters, there is a possible savings in private energy consumption which can amount to up to 7%. If this is flanked by the new price structures set by energy companies which enable consumers to optimise their consumption (for instance, to run the washing machine when this is most affordable), even greater saving are

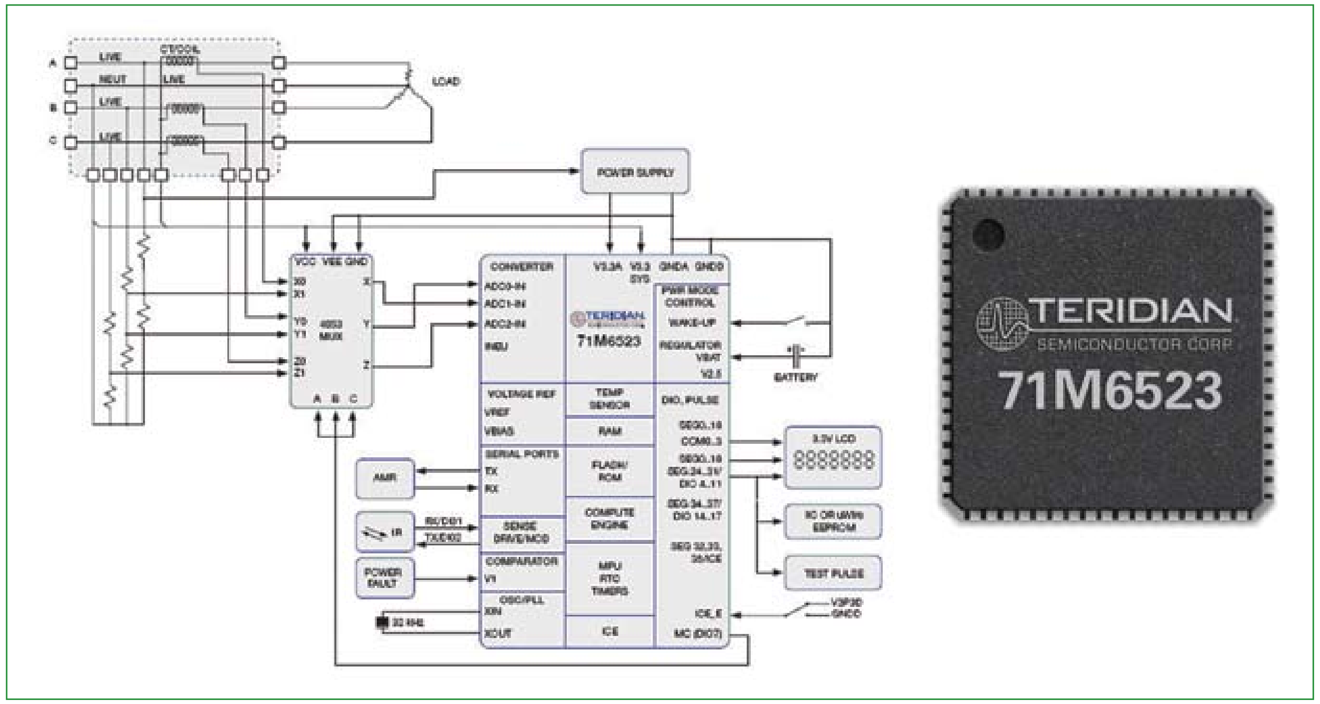

Figure 3: TERIDIAN semiconductor module (left) and simplified diagram (right) for 3-phase electricity meter with integrated functions for temperature and phase compensation, manipulation detection, slight fluctuations and a high level of repetition accuracy.

certainly possible.

Test runs with electronic meters

Since around 2007, test runs have been ongoing in Europe conducted by energy companies (on the use of electronic energy meters in private households. Throughout Europe, it is estimated that there are approx. 200 million energy meters. If all these counters should (within the next few years) be replaced by new "Smart Meters", a massive roll-out of these meters can be anticipated in Europe within the next several years. In the NAFTA region, one can reckon with similarly high unit quantities. Also in many Asian countries, work on the development of new energy concepts and electricity grid is under way – which will then require more than four times the quantity of Smart Meters estimated for Europe.

To gain experience with this new generation of meters, test runs are taking place (in Germany, for instance, since early 2008), conducted by the four major energy companies RWE, e.on, EnBW and Vattenfall.

In this context, one of the most widely known test runs in Germany is being conducted by RWE in Mülheim, in which up to 10,000 households will be connected. In this process (in addition to their technical quality), also the acceptance on the part of consumers and the handling of these devices are to be tested. The new meters are installed in place of the old Ferraris meter – and the data can be transmitted to the energy company – for instance, via Power Line Communication (known as PLC, data transmission via the electrical grid) or via a mobile communications interface (GPRS), which is partially integrated in the Smart Meter. With that, the possibilities for remote reading and remote interference by the grid service provider and/or the energy company are tested in order to receive more accurate consumption data more simply than before. In Figure 1, one can see such an electronic meter like the ones used in the household sector.

From this perspective, "Smart Meters" are an investment in the future. They supply a basic element for the further expansion of the grid to create a so-called "Smart Grid". With innovative systems, the evolution of a grid which integrates the various elements in the energy market – such as high-fluctuation energy capacities, de-centralised supply, block heat and power plants, solar and wind energy, etc. - is enabled.

Current Metering processes

Before the level of energy consumption can be determined, the current yield must be metered – correctly and accurately. That initially sounds simpler than it often is in practise. For this purpose, one must interfere with the current flow - and here, there are essentially four different metering principles for metering alternating current:

1) With a shunt
2) With a semiconductor component (hall sensor)
3) With an air-core coil (Rogowski coil)
4) With a coil featuring a magnetically soft core (current transformer)

In principle, all of these processes are suitable for metering alternating current – and with that, to determine energy consumption more or less accurately. For each process, there are already products on the market used in electronic meters. In the household sector, current intensities of 20A to 320A are typical (according to whether these are used in the 1-phase or 3-phase range – or, for instance, in the U.S., where the standard voltage is 120V).

Ideally, one expects from this current metering that they meet the following standards: highly linear across the entire current range, non-sensitive to DC components, non-sensitive to interspersed DC or AC fields along with the simplest-possible calibration of the phase response and the temperature dependency across the gauging range. None of the aforementioned principles, however, completely fulfils all of these conditions.

With current transformers based on nano-crystalline or amorphic homogenous cores, the best results can be achieved in this process in terms of accuracy, linearity and reliability.

Of course, the costs of physical metrology also play a role in the process. However, in relation to the total system costs for a "Smart Meter" (that is to say, including the analysis electronics, the data interface and the display unit) are not the decisive cost block. In this context, for example, the metering shunt is a rather simple and low-cost solution – and is already used in many countries where only single-phase grid are installed (i.e., in numerous European countries and in Asia). However, there are significant disadvantages with regard to linearity and temperature response – or also when an electrical isolation is required. In the U.S., therefore, due to the typically high amperages used there and to the applicable quality standards, primarily current transformers are used.

Figure 4: VAC current transformers for use in "Smart Meters", in different configurations (various intensities of current, with /without integrated insulation).

All in all, there are "Smart Meters" on the market which function according to one of the four principles. Current transformers, however, have inherent technical advantages compared to the other principles.

Current transformers for "Smart Meters"

For many years now, current transformers (and especially the applications in electronic meters) have been part of the Vacuumschmelze product portfolio. In this context, cores for these transformers are wound from rapidly-settling amorphic magnetic bands. Here, the material parameters are set so as to enable the achievement of cores with low permeability and very high linearity in the subsequent process steps. In Figure 2, the hysteresis response of such a core is illustrated. In the operating point at H = 0, one recognises the highly linear response of this current transformer.

Based on these material properties, these current transformers display significant advantages for the determination of electrical-energy consumption:

a) Broad tolerances range on the part of the output signal towards DC components in the current path ("DC stability")
b) Very constant phase error and constant temperature response which are very simple to compensate electronically
c) Very high linearity across the entire current Metering range – particularly also in the case of very low currents and outputs (such as, for instance, in energy-saving bulbs)
d) Very light metering errors in complex loads for the electrical grid (such as, for instance, in a household, where ohm, capacitive and inductive loads can occur simultaneously)
e) Very low interference due to stray fields (i.e., electronic devices in close proximity to a meter) due to the symmetry of the current transformers

As we have already mentioned in Item b), due to the phase and temperature response, an electronic compensation is required for all metering principles. Due to the outstanding properties of the current transformers, this compensation is possible with very simple and affordable ICs. The companies TERIDIAN and ANALOG DEVICES both already offer integrated circuitry for these current transformers, with which simple signal processing can be warranted. Figure 3 shows the finished TERIDIAN semiconductor module (left) and simplified diagram (right). The ICs are designed for three-phase electricity meters with integrated functions for temperature and phase compensation, manipulation detection, low fluctuations and high accuracy of the energy gauging (repetition accuracy).

Regarding the required specifications for "Smart Meters" (i.e., according to the European norms IEC and MID), there are currently several discussions still taking place. Many conditions for a future-oriented energy-supply grid and its components (particularly the "Smart Meters") have yet to be implemented in the form of requirements concerning the gauging principles.

It is clearly foreseeable that the standards regarding the components for a modern and reliable electrical-supply grid will continue to improve.

The company Vacuumschmelze is closely following the developments concerning standardisations and engineering standards – and is in the process implementing the specifications required by networks operators, energy-supply companies and standardisation committees in the form of products. Due to many years of experience in the magnetic-materials sector, we have a technically and economically future-oriented solution in our portfolio – with the aforesaid current transformers based on VITROPERM® or VITROVAC®.

In Figure 4, various configurations for current transformers (for various amperages) are indicated. In this context, also metallic insulations can be integrated when non-sensitivity to external influences is required.

Highly-linear cores with high dynamics, minimal interference, very good linearity and extremely high reliability enable meter manufacturers to place future-oriented "Smart Meters" on the market.

Conclusion

"Smart Meters" will squeeze the old electro-mechanical meters from the market. The requirements imposed upon this new generation of meters have, in this context, significantly increased – and particularly necessitate (on the part of metrology) highly precise and reliable components. For this purpose, the current transformers made by the company Vacuumschmelze offer in the totality of their properties a technically and commercially efficient solution. The portfolio of components is completed by magnet cores and transformers for the sector of data interfaces (i.e., PLC, "Power Line Communication") for these "Smart Meters".

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Special Report – Supplying the Power Grid

Real Investments Make Green Shoots

Reported by Cliff Keys, Editor-in-Chief, PSDNA

I recently participated in a research project in Germany, the heart of Europe, where the interviewer was very interested in the 'public view' of nuclear, fossil and renewable power generation. Just as it is becoming in the US, Europe has a high sensitivity to 'green' technology and 'green' is already a considered consumer choice – apart from the usual political and industrial bandwagon. Now it looks like a good proposition for private investment.

Interestingly, in what iSuppli Corp. believes could mark the beginning of the end of the use of fossil fuel and nuclear technologies for electrical power generation, the world's largest re-insurance company has announced an unprecedented effort to invest billions of Euros in solar power plants in North Africa.

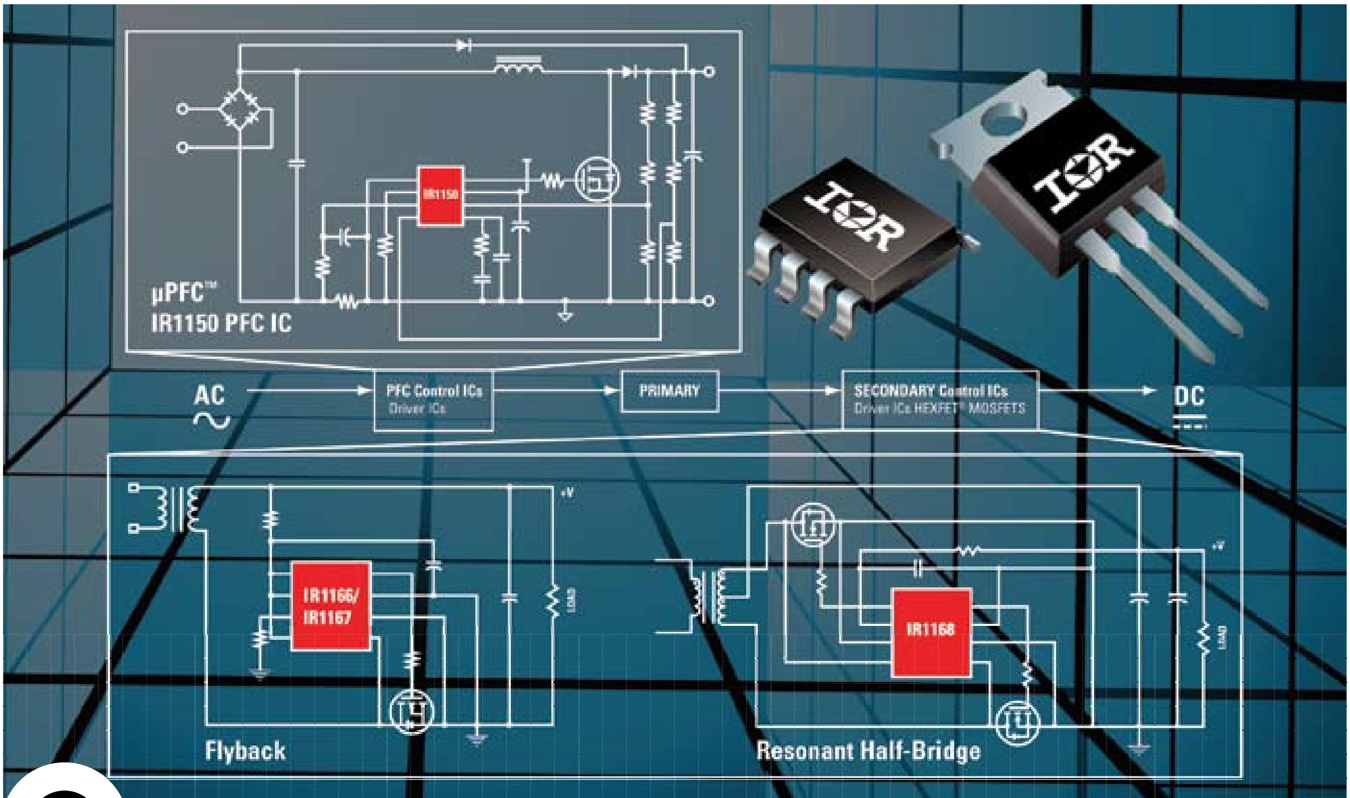
Shipments of solar power (PV) equipment grew by 81% in the second quarter of 2009 from the first, according to the latest analysis from IMS Research, indicating the worst of the industry's downturn may now be over. The quarterly data, which tracks PV inverter and module shipments, showed that in spite of the difficulties the industry is facing, over 1GW of PV equipment was shipped by manufacturers in Q209. However, for the first six months of 2009, shipments were still 34% down compared to the same period last year, mainly due to the sudden implosion of the Spanish market which adversely affected the worldwide figures.

But although shipments were sequentially up by more than 80% in Q2, year-to-date sales and shipments are still considerably down on 2008. Also, the PV market is strongly seasonal, and Q2 is typically much stronger than Q1. However, in 2007 and 2008, Q2's sequential growth was somewhat lower, at 75% and 57% respectively.

Trading conditions were reported to have been very tough in Q1, but it now looks like we are starting to turn a corner with more customers coming back to PV. Much hope is now being placed on newer markets, particularly the US and China, which are showing very promising signs. The US market is now being led by cash-rich utilities that are announcing multi-MW investments almost every week.

It seems that despite the widespread economic gloom that has been prevalent throughout the US and Europe, it finally looks as though the green energy sector together with the eagerly awaited power grid programs featured in this issue, are finally entering a phase of much-needed real investment. After all, real green shoots normally do appear about half a year later than announced in the political press!

www.powersystemsdesign.com/greenpage.htm



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<tr><th>Part Number</th><th>Package</th><th>V_{CC} (V)</th><th>V_{FET} (V)</th><th>Sw Freq. max (kHz)</th><th>Gate Drive ± (A)</th><th>V_{GATE} Clamp (V)</th><th>Min. On Time (ns)</th><th>Channel</th><th>RoHS</th></tr>
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250-3000</td><td rowspan="3">1</td><td>✓</td></tr>
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