Easy, Affordable and Fast Integration of IEC 61850 in Small Power System Devices

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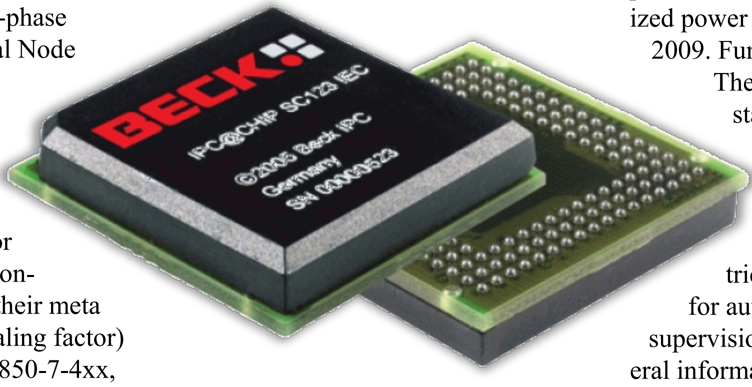
High financial and time expenditures for the implementation of IEC 61850 in control systems and other devices prevented so far a broad market penetration of the standard in the lower voltage levels and in distributed power generation. A reasonable and cost effective solution is now available with the Beck IPC@CHIP. The development of IEC 61850 conformant interfaces in power delivery systems – particularly renewable and decentralized power producers and consumers – can now be realized within very short time to market.

The standard series IEC 61850 [1] defines comprehensive information models, mechanisms for information exchange, a configuration language and a mapping to general communication protocols. It offers a unique and common architecture for many application domains [2,3]. The aspects are mainly the following:

General and user-specific information models like measured values of the voltage of the three-phase electrical network (Logical Node MMXU), rotor speed of a wind turbine (WTUR), switching position of the circuit-breaker (XCBR), temperature measured value (STMP) or the values of a PID loop controller (FPID) as well as their meta data (like SI-Units and scaling factor) are in the focus of IEC 61850-7-4xx, IEC 61850-7-3 and IEC 61400-25-2) [4-7].



Abstract methods for the change of information (ACSI - abstract communication service interface, according to IEC 61850-7-2) offer the most crucial services for the direct access (Read, Write, and Control), Reporting (spontaneous and cyclic; with monitoring of limits and changes), sequences of events (SoE: Sequence OF events), event archives in the devices (Logging), control, configuring and retrieving the self-description of the devices (IEC 61850-7-2 and IEC 61400-25-3) [8,9]. In addition two methods are defined for the transmission of critical information in real time: for the fast exchange of sensor data (typical several thousand sampled values per second of currents and voltages) and the fast exchange of critical information within the millisecond range.

Mapping of the abstract information and exchange methods to the application layer protocols as defined in IEC 61850-8-1, IEC 61850-9-1, IEC 61850-9-2, and IEC 61400-25-4 [10-13]. The communication stacks for transferring the messages use among other protocols mainly TCP/IP and Ethernet (IEC 61850-8-1 and IEC 61400-25-4).

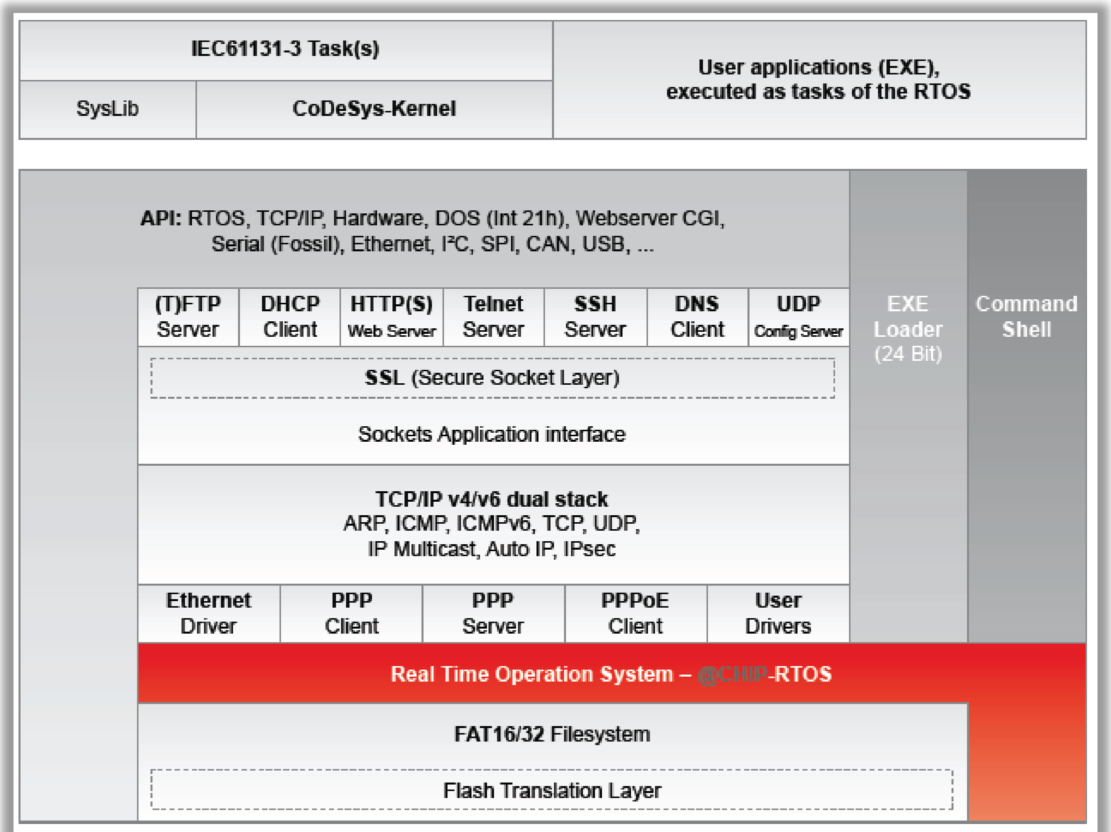
XML based configuration language for the complete description of a plant (IEC 61850-6) and a single device: Description of the plant topology, communication, information models, linkage of sources of information to destinations, and the binding of the models to the process and to internal equipment structures [14].

Toolbox for Multivendor systems

The standard series consists of 14 parts; published between 2003 and 2005. It is a tool box for building multivendor systems for substation protection and automation. The first extensions were published in 2007 in IEC TC 88 (Wind Turbines) with IEC 61400-25-4 for wind power plants. Extensions for hydro-electric power plants in 2007 and for the decentralized power resources followed in 2009. Further parts are in process.

The first fourteen parts of the standard series and the extensions (above all the information models) cover crucial information needed in the electrical power supply network for automation, protection and supervision. Meanwhile many general information models for the applications in general automation domains are defined in the second edition of part IEC 61850-7-4. One of the most crucial and interesting parts is part IEC 61850-90-7 (IEC 61850 object models for inverters in distributed energy resources (DER) systems).

The issue of the information exchange by means of MMS (Manufacturing Message Specification - ISO 9506) and ASN.1 (Abstract Syntax Notation 1 - ISO 8824/8825) – although it is required in the communication stacks of devices – however it is of subordinated importance, if it concerns the contents of the standards. With the realization of standard-



IPC@CHIP® RTOS architecture

conformant products MMS is key because before two devices can communicate in the client-server relation there is a need of an MMS stack on each end of the communication channel – a server and a client.

Applications of IEC 61850

IEC 61850 is used globally in many thousand plants of medium and high voltage networks. All large manufacturers of substations such as ABB, AREVA, GE, Siemens, Toshiba and many smaller manufacturers use IEC 61850 as the preferred solution. In the context of many Smart Grid projects in North America, in Asia and Europe IEC 61850 is regarded as the most important protocol standard. Beyond that, IEC 61850 – particularly because of the uniform and recently defined general information models – is used increasingly also in industrial and process automation systems.

In the contrast to the fieldbus standard IEC 61158 with (too) many standardized solutions in a single standard with almost 100 parts, IEC 61850 has only one protocol stack for TCP/IP-based client-server communication and two simple protocols using native switched Ethernet for real time communication. In many enterprises IP networks are very common. This allows directly and without special modifications to directly employ MMS based client-server communication. All information models of all devices can be accessed this way, fast and without detours from everywhere – also safely with TLS (Transport Layer Security). TLS is required by IEC 61850-8-1 and selected in IEC 62351 – the sister standard of IEC 61850.

These solutions could be achieved so far mostly just by very high financial and temporal expenditures. The implementation of the MMS client-server stack was usually realized by purchasing extensive and relatively expensive licensed software packages. The expected expenditures for porting the licensed MMS software and/or the development of MMS software were estimated so high that in many cases the application of IEC 61850 was questioned – especially when it comes to small devices.

Although the focus of the application of the standard series clearly is on the models and configuration language (which are independent of MMS), the implementation mainly depends on the acceptance of MMS. This is especially true for the use of IEC 61850 in simpler applications. MMS is however necessary for standard-conformant information exchange between clients and servers – no question. IEC 61850 does not support alternative protocols fortunately! The question is now, are there alternative MMS implementations – above all – for the application of IEC 61850 for simple applications? Yes! Thanks to the efforts taken by SystemCorp (Bentley, Western Australia) [15] and Beck IPC (Pohlheim, Germany) [16] to implement IEC 61850 on a small footprint of a simple embedded controller: IEC61850@CHIP.

Chip based solution

At the Hanover fair 2010 Beck IPC presented the integrated solution for IEC 61850 successfully in co-operation with SystemCORP Pty Ltd. (Bentley, Western Australia) at the Beck IPC booth. The embedded controller demonstrated was an industrial proven component that is on the market for five years in industrial automa-

tion systems. It is a modular controller chip (IPC@CHIP). The resonance of the many hundred booth visitors exceeded expectations of all involved people of Beck and SystemCorp by far. In the meantime there are many applications all over that use the Beck IPC controller.

The substantial advantage of the embedded controller based solution is its high efficiency, performance, and the minimum expenditure needed for the implementation of IEC61850-based interfaces for clients and servers. This platform is very economical. From a programming point of view it is a PC and a PLC (programmable logic controller) – it can be programmed with C/C++ as well as with IEC 61131-3 (CoDeSys). All license costs for the compilers and the IEC 61850 communication stack and API (application program interface) are already included in the chip price. Products based on other stacks may require a run-time license fee for the IEC

61850 stack per device that is more expensive than the complete chip. Not to speak about the needed efforts of porting the stack software to your platform (HW and SW). This may take many months and even years – the author has been contacted by many companies that complained that IEC 61850 is quite complex and too expensive to implement (even when using available third party software).

The IPC@CHIP SC123 and SC143 are equipped with the real-time and multitasking operating system IPC@CHIP-RTOS. The following software functions are integrated in the RTOS of the SC123/SC143: IEC 61850, IEC 61400-25, TCP/IPv6/IPv4, SSL, SSH, IPSec, PPPoE, API for CAN, IEC 61131-3 (CoDeSys, PLC), and C/C++

The software architecture is very comprehensive, compact and extremely efficient (Figure above).

The technical specification of the Chips (SC123 und SC143) could be found in the attached document.

For different applications regarding simple integration, mass production and performance three packages are offered.

IEC 61850 lite implementation

All crucial data models, communication services and the device configuration language (SCL) are realized in the stack and API running on the chip. All models from the applications protection and automation substations of any voltage level including power generation and distribution, monitoring of the power quality, automation and monitoring of hydro-electric power plants, wind turbines, decentralized energy generation such as photovoltaic, combined heat and power, diesel generators, battery storage stations, car charging stations to name just a few. The models of the new part IEC 61850-90-7 [17] are supported. The models for PV inverter have already been implemented on the SC143 by major PV inverter vendors in 2010 and 2011.

All models needed for the applications can be uploaded by a standardized SCL files by ftp on the chip. Thus the model and communication configuration is entirely accomplished by a standardized IEC 61850-6 file (SCL – system configuration language).

The IEC 61850 software stack and API can be started by the application easily as client or as server. Both applications can co-exist on the IPC@CHIP at the same time. The stack supports IEC 61850 services inclusive GOOSE and transmission of sampled values.

The SystemCorp IEC 61850 stack and API offers a very simple interface to the application software in the form of a few calls (and call-backs) like for example "Read", "Write", "Update", and "Control". Only a binding table must be defined, with which the real values of the process or of the application are bound (linked to) the information models according IEC 61850. This table is used, in order to describe the appropriate relations between model and the real world. That relation is implemented in the SCL file by private XML elements, which are interpreted by the IEC 61850 stack and API software as well as by the application software. This model (SCL file) is used for the configuration of the server **and** the client. The API docu-

mentation is available online [18]. A video explaining the use of the API function calls and the models at the server and the client side is available [19].

All services like Read, Write, Reporting, GOOSE, data sets and so on are completely configured by a SCL file. Using the same application data, one can configure at any time further logical devices, control blocks and data records simply by an extended or new SCL file transferred to the chip.

Ready to go devices

Beside the chips Beck IPC offers also ready to go modules (com.tom) – the only need is to let your application code understand the few API calls and call-backs – that's all you need to communicate your data values with IEC 61850 models and services. The development of different gateways to, for example, CAN, IEC 60870-5-10x,

Profibus, DNP3 or Modbus can be realized in short time. This reduces the time to marked tremendously. The modules can be equipped with a data base system which implements the binding of different protocols by configuration software which is based on a Windows configuration tool. Protocol stacks for IEC 60870-5-101/104/103 and DNP3.0 are likewise available.

The com.tom solution for telecontrol is suitable for applications with existing WAN connectivity and existing process control and monitoring applications. Communication of the com.tom BASIC solutions can also directly communicate with a dedicated Web portal. The com.tom communicates with Ethernet and other existing network infrastructures like WiFi, Bluetooth, or GPRS.

The communication with the process can be realized over a serial interface or over digital inputs or outputs. The digital inputs and outputs can be processed additionally with simple PLC functions.

The integrated Web server on the com.tom BASIC provides also a simple WEB based editor for a Web PLC that can be used to for simple control algorithms.

Development Kit Beck IPC DK61

For a cost effective and fast start into the world of IEC 61850 the development kit DK61 is likely the best approach.

The IPC@CHIP DK61 development kit is a complete development system for the embedded controller IPC@CHIP SC123 and SC143.

It contains the Paradigm C/C++ compiler with IPC@CHIP RTOS debugger and many further tools, which can be applied for the simplified development of C/C++ and IEC 61131-3 (CoDeSys) applications on the Embedded controller SC123 and SC143.

Despite the comprehensive hardware of the development board, which makes all interfaces of the SC123 and SC143 available, a start-up is possible within minutes rather than hours or days. This is due to the installed RTOS, the „Getting Started“ manuals and the examples that come with the DK61 development kit.

The extensive hard and software equipment allow a fast and efficient development of customized applications within hours and days.

All aspects of the IEC 61850 Solution on the IPC@CHIP, described above, are available and directly applicable also on the development kit. An extensive example of use with a model for process values (inputs and outputs), with reporting and GOOSE is contained in the kit. The source code of the C application program is likewise provided. C programmers can immediately begin with the programming of their application and – as described in the example – communicate their data values within a short time by IEC 61850.

Special knowledge of MMS and ASN.1 is not necessary – applications can directly use the simple API. The development of an extensive protocol stack and a user interface are not needed – the focus is now on the application of the standard series for the realization of smarter power delivery systems.

The SystemCorp stack and API is available on various embedded controller platforms, e.g., Arm 9 or Arm 11 controllers that run on Linux. The stack and API could be ported to all major platforms; DLLs and libraries for Windows and PCs are also available.

Reduce time to market

Using the approaches of SystemCorp (Lite Implementation and API) and Beck IPC (embedded controller with everything ready-to-go) will help you **control**, **predict** and **reduce** your **time to market**. If the market requires IEC 61850 integrated, e.g., into your PV converter or other devices for controlling or monitoring the electrical system (or other applications) there are several approaches (depending on the time to deliver the device to the customer) you could choose from:

Very short time to market
(week(s) up to a very few months):
Recommended to use the Beck IPC com.tom ready-to-go box with Beck IPC chip as external or internal module.

Short time to market
(few months):
to use the Beck IPC Chip on a small printed circuit board as internal module.

Longer time to market
(several months):
to use the SystemCorp software on the controller of an available design or design a new HW with a new powerful embedded controller, e.g., from Beck (running RTOS) or TQ (running Linux).

In the attachment there is a description of the path to a short time to market using the SystemCorp stack and API.

Further information

More information on the IPC@CHIP can be found in English and German: http://www.beck-ipc.com

Details of the IEC 61850 Stack and API implemented on the IPC@CHIP are available at: http://systemcorp.com.au/PIS10API

General information, trends and news on IEC 61850: http://blog.iec61850.com

Monitoring and Control of Power Systems and Communication Infrastructures based on IEC 61850 and IEC 61400-25 (English): http://www.nettedautomation.com/download/pub/DT-Tampa-Paper_2010-03-24.pdf

User Groups:
http://www.iec61850.ucaiug.org
http://www.USE61400-25.com

[1] IEC 61850: Communication networks and systems for power system automation. Some 20 parts by end of 2011: http://blog.iec61850.com/2012/01/status-of-parts-of-iec-61850-series.html

[2] IEC 61850 on a page (English): http://www.nettedautomation.com/standardization/IEC_TC57/WG10-12/iec61850/What-is-IEC61850.pdf

[3] Video on the basics of IEC 61850: http://blog.iec61850.com/2012/02/video-with-brief-introduction-to-iec.html

[4] IEC 61850-7-410: Communication networks and systems for power utility automation – Part 7-410: Hydroelectric power plants – Communication for monitoring and control.

[5] IEC 61850-7-420: Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes.

[6] IEC 61850-7-3: Communication networks and systems in substations – Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes.

[7] IEC 61400-25-2: Wind turbines – Part 25-2: Communications for monitoring and control of wind power plants – Information models.

[8] IEC 61850-7-2: Communication networks and systems in substations – Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI).

[9] IEC 61400-25-3: Wind turbines – Part 25-3: Communications for monitoring and control of wind power plants – Information exchange models.

[10] IEC 61850-8-1: Communication networks and systems in substations – Part 8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3.

[11] IEC 61850-9-1: Communication networks and systems in substations – Part 9-1: Specific Communication Service Mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link.

[12] IEC 61850-9-2: Communication networks and systems in substations – Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3

[13] IEC 61400-25-4: Wind turbines – Part 25-4: Communications for monitoring and control of wind power plants – Mapping to communication profile.

[14] IEC 61850-6: Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in electrical substations related to IEDs.

[15] System Corp Pty Ltd, Bentley, Western Australia: http://systemcorp.com.au

[16] Beck IPC GmbH, Pohlheim: www.beck-ipc.com

[17] IEC 61850-90-7: IEC 61850 object models for inverters in distributed energy resources (DER) systems (to be published early 2012) http://blog.iec61850.com/2011/08/pv-power-to-destabilize-european-power.html

[18] API online documentation: http://systemcorp.com.au/PIS10API

[19] Video on the use of SCL files for configuration of a server and a client: http://blog.iec61850.com/2012/02/video-on-use-of-iec-61850-6-scl-to.html

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Dipl.-Ing. Karlheinz Schwarz (president of Schwarz Consulting Company, SCC, and owner of NettedAutomation GmbH; Karlsruhe/Germany) specializing in distributed automation systems. He is involved in many international standardization projects (IEC 61850 – utility automation, DER, hydro power, IEC 61400-25 – wind power, IEC 61158 - Fieldbus, ISO 9506 – MMS, …) since 1984. He is engaged in representing main industry branches in the international standardization of real-time information modeling, configuration, and exchange systems. Core services are consulting and training of utility personal, system integrators, consultants, and vendors. He has educated more than 3,600 experts from more than 800 companies and more than 80 countries. The training courses are considered to be outstanding. Mr. Schwarz is a well-known authority on the application of mainstream information and communication technologies in the utility industry and general automation domain.

NettedAutomation GmbH
Information & Communication Systems

Annex:

What does IEC 61850-90-7 (IEC 61850 object models for inverters in distributed energy resources (DER) systems) provide?

The following is based on IEC 61850-90-7 (final draft 2012-02)

The main purpose of the document is to define **information models** of the known functions of PV inverters. These functions are those that are **already implemented** in today's controllers of inverters installed all over. The information models defined in IEC 61850-90-7 just define **standard names** of the "signals" found in most PV inverters – the standard just follows the market. The standard also provides a **common way to access and distribute the information** needed to configure, control, and monitor real inverters. Due to the single model and communication profile (independent of the vendors) it is easy to communicate with the inverters of many different vendors with one single standard.

The advent of decentralized electric power production is a reality in the majority of the power systems of the world, driven by the need for new types of energy converters to mitigate the heavy reliance on non-renewable fossil fuels, by the increased demand for electrical energy, by the development of new technologies of small power production, by the deregulation of energy markets, and by increasing environmental constraints.

These pressures have greatly increased the demand for Distributed Energy Resources (DER) systems which are interconnected with distribution power systems, leading to high penetrations of these variable and often unmanaged sources of power. No longer can they be viewed only as "negative load". Their large numbers, their unplanned locations, their variable capabilities, and their fluctuating responses to both environmental and power situations make them difficult to manage, particularly as greater efficiency and reliability of the power system is being demanded.

This paradigm shift in management of power systems can be characterized by the following issues:

The numbers of interconnected DER systems are increasing rapidly. The advent of decentralized electric power production is a reality in the majority of power systems all over the world, driven by many factors:

- The need for new sources of energy to mitigate the heavy reliance on externally-produced fossil fuels.
- The requirements in many countries and US states for renewable portfolios that have spurred the movement toward renewable energy sources such as solar and wind, including tax breaks and other incentives for utilities and their customers.
- The development of new technologies of small power production that have made, and are continuing to improve, the cost-effectiveness of small energy devices.
- The trend in deregulation down to the retail level, thus incentivizing energy service providers to combine load management with generation and energy storage management.
- The increased demand for electrical energy, particularly in developing countries, but also in developed countries for new requirements such as Electric Vehicles (EVs).
- The constraints on building new transmission facilities and increasing environmental concerns that make urban-based generation more attractive.

These pressures have greatly increased the demand for Distributed Energy Resources (DER) systems which consist of both generation and energy storage systems that are interconnected with the distribution power systems.

DER systems challenge traditional power system management. These increasing numbers of DER systems are also leading to pockets of high penetrations of these variable and often unmanaged sources of power which impact the stability, reliability, and efficiency of the power grid. No longer can DER systems be viewed only as "negative load" and therefore insignificant in power system planning and operations. Their unplanned locations, their variable sizes and capabilities, and their fluctuating responses to both environmental and power situations make them difficult to manage, particularly as greater efficiency and reliability of the power system is being demanded.

At the same time, DER devices could become very powerful tools in managing the power system for reliability and efficiency. The majority of DER devices use inverters to convert their primary electrical form (often direct current (dc) or non-standard frequency) to the utility power grid standard electrical interconnection requirements of 60Hz or 50Hz and alternating current (ac). Not only can inverters provide these basic conversions, but inverters are also very powerful devices that can readily modify many of their electrical characteristics through software settings and commands, so long as they remain within the capabilities of the DER device that they are managing and within the standard requirements for interconnecting the DER to the power system.

DER systems are becoming quite "smart" and can perform "autonomously" most of the time according to pre-established settings or "operating modes", while still responding to occasional commands to override or modify their autonomous actions by utilities and/or energy service providers (ESPs). DER systems can "sense" local conditions of voltage levels, frequency deviations, and temperature, and can receive emergency commands and pricing signals, which allow them to modify their power and reactive power output. These autonomous settings can be updated as needed. To better coordinate these DER autonomous capabilities while minimizing the need for constant communications, utilities and ESPs can also send schedules of modes and commands for the DER systems to follow on daily, weekly, and/or seasonal timeframes.

Given these ever more sophisticated capabilities, utilities and energy service providers (ESPs) are increasingly desirous (and even mandated by some regulations) to make use of these capabilities to improve power system reliability and efficiency.

Inverter configurations and interactions

Bulk power generation is generally managed directly, one-on-one, by utilities. This approach is not feasible for managing thousands if not millions of DER systems.

DER systems cannot and should not be managed in the same way as bulk power generation. New methods for handling these dispersed sources of generation and storage must be developed, including both new power system functions and new communication capabilities. In particular, the "smart" capabilities of inverter-based DER systems must be utilized to allow this power system management to take place at the lowest levels possible, while still being coordinated from region-wide and system-wide utility perspectives.

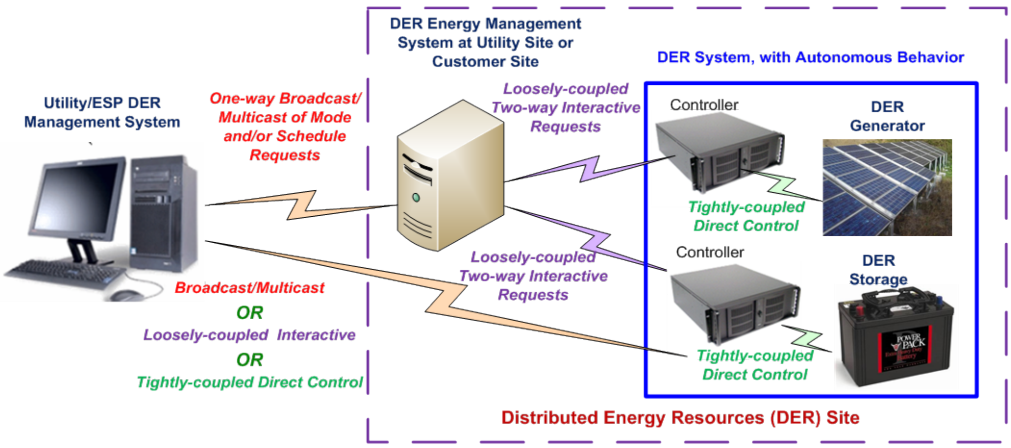
This "dispersed, but coordinated intelligence" approach permits far greater efficiencies, reliability, and safety through rapid, autonomous DER responses to local conditions, while still allowing the necessary coordination as broader requirements can be addressed through communications on an as-needed basis. Communications, therefore, play an integral role in managing the power system, but are not expected or capable of continuous monitoring and control. Therefore the role of communications must be modified to reflect this reality.

Inverter-based DER functions range from the simple (turn on/off, limit maximum output) to the quite sophisticated (volt-var control, frequency/watt control, and low-voltage ride-through). They also can utilize varying degrees of autonomous capabilities to help cope with the sophistication.

At least **three levels of information exchanges** are envisioned:

- **Tightly-coupled interactions** focused on direct monitoring and control of the DERs with responses expected in "real-time".
- **Loosely-coupled interactions** which request actions or "modes" that are interpreted by intelligent DER systems for undertaking **autonomous reactions** to local conditions or externally provided information. Information is then sent back on what actions they actually performed.
- **Broadcast/multicast** essentially one-way requests for actions or "modes", without directly communicated responses by large numbers of DERs.

These different DER management interactions are shown in the following figure.



DER Management: Interactions between Components

Inverter functions

Inverter functions range from the simple to the complex. Most inverter functions are based on settings or curves that allow them to respond autonomously to local conditions, while some require direct control commands:

- **Immediate control functions** for inverters
  - Function INV1: connect / disconnect from grid
  - Function INV2: adjust maximum generation level up/down
  - Function INV3: adjust power factor
  - Function INV4: request active power (charge or discharge storage)
  - Function INV5: request action through a pricing signal

- **Volt-var management modes**
  - Volt-var mode VV11: available vars mode with no impact on watts
  - Volt-var mode VV12: maximum var support mode based on maximum watts
  - Volt-var mode VV13: static inverter mode based on settings
  - Volt-var mode VV14: passive mode with no var support

- **Frequency-watt management modes**
  - Frequency-watt mode FW21: high frequency reduces active power or low frequency reduces charging
  - Frequency-watt mode FW22: constraining generating/charging by frequency
  - Frequency-watt mode FW23: watt generation/absorption counteractions to frequency deviations

- **Dynamic reactive current support during abnormally high or low voltage levels**
  - Dynamic reactive current support TV31: volt-var support during abnormally high or low voltage levels

- **Functions for "must disconnect" and "must stay connected"**
  - "Must disconnect" MD curve
  - "Must stay connected" MSC curve
  - Reconnect settings

- **Watt-power factor management modes**
  - Watt-power factor WP41: feed-in power controls power factor (parameters)
  - Watt-power factor WP42: feed-in power controls power factor (curves)

- **Voltage-watt management modes**
  - Voltage-watt mode VW51: smoothing voltage deviations by watt management
  - Voltage-watt mode VW52: charging by voltage

- **Non-power-related modes**
  - Temperature-function mode TMP: ambient temperature indicates function
  - Pricing signal-function mode PS: pricing signal indicates function to execute

- **Parameter setting and reporting**
  - Function DS91: modify inverter-based DER settings
  - Function DS92: event/history logging
  - Function DS93: status reporting
  - Function DS94: time synchronization

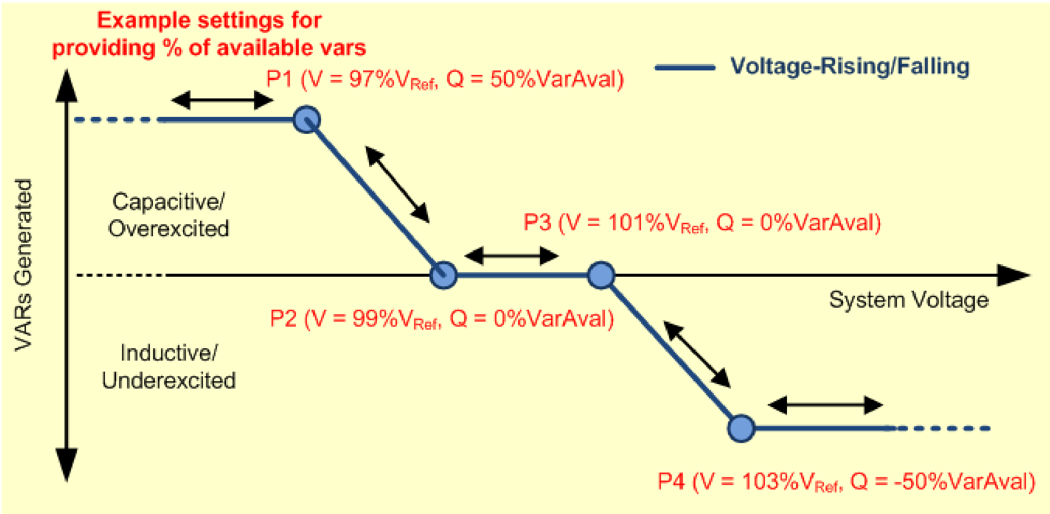
It is expected that additional functions will be added in the future, for instance for handling intentional and unintentional islanding.

The following figure provides an example of volt-var settings for this mode. It is assumed that the var value between VMin and V1 is the same as for V1 (shown as 50% VArAval, in this example). The equivalent is true for the var value between V4 and VMax (which is assumed to be 50% VArAval in this example).

Example Settings

Voltage Array (% VRef)		VAr Array (% VArAval)	
V1	97	Q1	50
V2	99	Q2	0
V3	101	Q3	0
V4	103	Q4	-50

VAr Ramp Rate Limit – fastest allowed decrease in VAR output in response to either power or voltage changes	50 [%VArAval/second]
VAr Ramp Rate Limit – fastest allowed increase in VAR output in response to either power or voltage changes	50 [%VArAval/second]
The time of the PT1 in seconds (time to accomplish a change of 95%).	10 seconds
Randomization Interval – time window over which mode or setting changes are to be made effective	60 seconds



The information needed for this application is defined in corresponding Logical Nodes of IEC 61850-90-7 and IEC 61850-7-4. From an implementation point of view the standard just provides an external view of the inverter internal information and information exchange (**for the inverter functions, e.g., volt-var control**). It could be assumed that the functions are **already implemented in the existing inverter controller**. Possible implementation architectures are: