NETL Modern Grid Initiative
Powering our 21st-Century Economy

A Compendium of Modern Grid Technologies

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INTRODUCTION

A fully modernized grid is essential to provide service that is reliable, secure, cost-effective, efficient, safe, and environmentally responsible. To achieve the vision of the Modern Grid, a wide range of technologies must be developed and implemented. These technologies can be grouped into the following five Key Technology Areas (KTA's):

- **Integrated Communications** – High-speed, fully integrated, two-way communication technologies that make the modern grid a dynamic, interactive "mega-infrastructure" for real-time information and power exchange. An open architecture creates a plug-and-play environment that securely networks grid components and operators, enabling them to talk, listen and interact.
- **Advanced Components** – Advanced components play an active role in determining the electrical behavior of the grid. These power system devices apply the latest research in materials, superconductivity, energy storage, power electronics, and microelectronics to produce higher power densities, greater reliability and power quality, enhanced electrical efficiency that produces major environmental gains and improved real-time diagnostics.
- **Advanced Control Methods** – New methods and algorithms monitor power system components, enabling rapid diagnosis and timely, appropriate response to any event. They also support market pricing and enhance asset management and efficient operations.
- **Sensing and Measurement** –Technologies that enhance power system measurements and enable the transformation of data into information. They evaluate the health of equipment, the integrity of the grid and support advanced protective relaying. They enable consumer choice and demand response, and help relieve congestion.
- **Improved Interfaces and Decision Support** –The modern grid will require wide, seamless, often real-time use of applications and tools that enable grid operators and managers to make decisions quickly. Decision support and improved interfaces will enable more accurate and timely human decision making at all levels of the grid, including the consumer level, while also enabling more advanced operator training.

This document provides a living compendium of technologies categorized by Key Technology Area -- both individual ones as well as some that have been integrated with others. Some are commercially available and others are still under development. Its content is based on website searches and networking conversations with industry,

government and academia experts. Users should consult the listed references to ensure they obtain the latest information.

INTEGRATED COMMUNICATIONS

Table 1: Integrated Communications

Integrated Communications			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References***
Internet 2	~3 Years	Internet 2 development is led by more than 200 universities for next-generation high speed internet backbone. IPv6 extends Internet IP address scheme to 6 octets which is desirable for BPL based ISP services. With high performance backbone and MPLS QoS services, integration of QoS sensitive applications is directly supported.	http://www.internet2.edu/; http://www.ipv6.org/
BPL	1 Year (Many initial pilots performed and some system wide deployments are underway.)	Broadband over Power Line (BPL) is a technology that allows Internet data to be transmitted over utility power lines. BPL works by modulating high-frequency radio waves with the digital signals from the Internet. These radio waves are fed into the utility grid at specific points. They travel along the wires and pass through the utility transformers to subscribers' homes and businesses. Little, if any, modification is necessary to the utility grid to allow transmission of BPL. This mode has not yet been widely deployed in the United States, but it has been implemented in a few other countries, with varying results. Some engineers fear that BPL will interfere with fire, police, shortwave, land mobile, and other radio systems important to national security. Amateur radio operators have voiced their concerns as well. Standards for BPL are now in development and will be needed for broader market acceptance. BPL is effective over short distances at 2-50 MHz and can achieve data transfers of 20 Mbps to 100 Mbps	http://www.amperion.com/; http://www.currenttechnologies.com/; http://www.ambientcorp.com/; http://www.homeplug.org/; http://www.bpltoday.com/
Hybrid Fiber Coax (HFC)	~2 Years	HFC architecture uses fiber to carry voice, video and data from the headend or central office to the optical node serving a neighborhood. At the optical node, the downstream optical signal is converted to an electrical signal and carried via coax to drops at customer locations to provide service (televisions, computers, telephones, etc.). A single optical node will typically support a number of coaxial distribution feeds. Due to the popularity of bi-directional services such as Video-on-Demand, high-speed Internet and Voice over IP, cable operators have begun plant upgrades that provide these services.	http://bwcecom.belden.com/college/techpprs/fgelwtp.htm; http://www.iec.org/online/tutorials/hfc_dwdm/; http://www.iec.org/online/tutorials/hfc_tele/

* The website/internet references are accurate as of April 4, 2007; however, the content and address for websites are subject to change.

Integrated Communications			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References***
Power Line Carrier	Available now	AMI deployment requirements have led to the development of proprietary PLC solutions which also support grid control initiatives such as load shedding. The Two-Way Automatic Communication System (TWACS®) is a fixed network utility communication system that uses patented technologies to communicate over electric power lines or via short hop radio frequency (RF), providing low-cost, highly-reliable, two-way communication between the utility and the consumers of electricity, gas, propane and pit-set meters. The TWACS system uses the existing power lines for data transmission, and since it modulates the waveform at the zero crossing point, it uses the utility's network at the frequency for which it was designed. TWACS technology is a state-of-the-art, proven reliable, multi-functional, power line and radio frequency communication system with full two-way access to and from the meter. Advanced TWACS systems are being developed that can provide 1 kps to 2 kps data transfers for PLC. Low speed PLC could provide a solution to the final connectivity to the customer problem if it is already installed, but first time installation costs are not insignificant.	http://www.twacs.com/ and private communication with Marty Gordon of NRECA CRN
Narrowband PLC (IEC 61334-5) DLMS	Developed and deployed in Europe; Limited deployment in North America	Use of narrowband PLC for access between the utility and the customer site has been greater in Europe than in North America because of the higher number of customers connected to each low-voltage transformer. Therefore, the international standards for customer access via narrowband PLC are mostly European-based. The most popular narrowband PLC systems in North America are used within the customer site. The regulatory environment for narrowband PLC differs considerably between Europe and North America. While the FCC permits use of any frequency below 540kHz, CENELEC defines five different bands ranging up to 148.5kHz. Each of the individual bands has restrictions on their use.	http://www.iec.ch - IEC; http://www.dlms.com/ – DLMS User Association
WiFi	Available now	WiFi using IEEE 802.11b is effective for in office or in home use, but has a low range of only about 100 m, provides lower quality of service than conventional coaxial cable service, requires encryption for security, can be implemented at low cost, and may work fine with wireless sensors in a substation environment. Data transfer ranges from 5 Mbps to 10 Mbps.	F. Goodman, et.al., "Technical and System Requirements for Advanced Distribution Automation" EPRI Technical Report 1010915, June 2004. Utility Automation Magazine Article, May 2006, "Utility Data Communications: New and Emerging Wireless Technologies", Jai Belagur & Tom Lebakken. http://uaelp.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=254497&VERSION_NUM=3&p=22
WiMax (4G)	~3 Years	WiMax can provide the requisite long distance communications out beyond 10 miles and in some instances beyond 30 miles at data transfer rates of 75 Mbps. WiMax using IEEE 802.16 can communicate from point to point with different vendors. WiMax can communicate out-of sight via IEEE 802.16e and can communicate with moving trucks or cars. It can be the spine of a T&D communication system that will support WiFi applications for substation or distribution automation.	http://www.wimaxforum.org/home/; Utility Automation Magazine Article, May 2006, "Utility Data Communications: New and Emerging Wireless Technologies", Jai Belagur & Tom Lebakken http://uaelp.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=254497&VERSION_NUM=3&p=22

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Cellular (3G)	~2 Years	Using the Short Message Service (SMS) function of a digital cellular network can be applied to provide low cost substation automation to control and monitor substation performance when small bursts of control information or monitoring data is needed; however, SMS of a digital cellular network will not be able to provide the Quality of Service that on-line substation control and monitoring may require.	T.Tommila, O. Venta and K. Koskinen, "Next Generation Industrial Automation-Needs and Opportunities," Automation Technology Review, 2001; http://www.3gpp.org; http://www.3gpp2.org; http://uaelp.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=254497&VERSION_NUM=3&p=22
TDMA Cellular Wireless - IS-136	Available now	Time Division Multiple Access (TDMA), developed by the ANSI-accredited Telecommunications Industry Association (TIA), is digital transmission technology that allocates unique time slots to each user within each channel. The two major (competing) systems that split the cellular market are TDMA and CDMA. Because of its adoption by the European standard GSM, and the Japanese Digital Cellular (JDC), TDMA and its variants are currently the technology of choice throughout the world. However, third-generation wireless networks will use CDMA, not TDMA.	http://www.tiaonline.org/
CDMA Cellular Wireless - IS-95	Available now	Code Division Multiple Access (CDMA) for Spread Spectrum has become the technology of choice for the future generation of wireless systems. IS-95 based CDMA system developed by the ANSI-accredited Telecommunications Industry Association (TIA) has been widely deployed in the U.S. IS-95 evolves to CDMA-2000 for third-generation cellular systems.	http://www.tiaonline.org/
Very Small Aperture Terminal (VSAT) Satellite	Available now	Satellite can provide new solutions for remote monitoring and control of T&D substations providing extensive coverage. VSAT satellite services are readily available and can be tailored to support substation monitoring and provide GPS based location and time synchronization (important for successful use of PMUs). The system can be implemented quickly, but the cost will be high, except for remote locations. Satellite communication can be also effected by severe weather and storms, and have long communication delays for round trips. Several satellite-based services are available. VSAT is the type most often used by utilities. It uses a very small transmitting antenna (0.6 to 3.8 meter) and is star-connected with a hub at the center of the network with dedicated lines running to the host computer. The hub has a large antenna aimed at the satellite. The hub is very expensive and is usually owned by the VSAT vendor.	Y.Hu,, V.O.K. Li, "Satellite-" Internet: A Tutorial", IEEE Communications Magazine, vol. 39, pp. 154-162, March 2001.
WiFiber	Available now	This system is dubbed "WiFiber" by its creator, GigaBeam, a Virginia-based telecommunications startup. Although the technology is wireless, the company's approach is more of an alternative to fiber optics than to Wi-Fi or Wi-Max. It is also known as "Optical Wireless".	http://www.gigabeam.com/
Zigbee Wireless	Available now	Zigbee (by Cirronet) uses frequency hopping spread spectrum (FHSS) radio technology, which offers reliable, long range performance and immunity against jamming and interference.	http://www.cirronet.com/zigbee.htm; http://www.zigbee.org/en/index.asp

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Z-Wave Wireless	Available now	Z-Wave™ is a wireless RF-based communications technology designed for residential and light commercial control and status reading applications such as meter reading, lighting and appliance control, HVAC, access control, intruder and fire detection, etc. Z-Wave is based upon an RF chipset from Zen-sys that provides two-way mesh networking of intelligent devices. The networks communicate via radio at 908.4 MHz in the U.S. and 868 MHz in Europe. Both are unlicensed bands. Maximum bandwidth is just 9.6K bit/sec but is adequate for the commands sent over the network. The technology can link as many as 232 Z-Wave-enabled devices and adapters in a mesh network along with a controller, such as a handheld remote, that sends out commands. In addition to receiving commands, the chip in each adapter can act as a relay to extend the range of the network. This mesh technology makes it easy to set up and allows for lower power consumption and a low-cost chip.	http://www.z-wavealliance.org/modules/start/; http://www.zen-sys.com/
Data over Voice Lines	In use for many years	Voice-grade telephone connections (standard 3 kHz voice circuits) are made either by dialing or by being wired in the telephone company's central office. They remain connected until the service is discontinued. The user has no knowledge of where or how the circuit is routed between the two end-points, unless the telephone company is specifically requested to provide diversity for security and availability purposes. Point-to-point circuits are cost effective for high-speed communication between two devices, but they are more expensive when compared to dial-up applications where the circuit is connected and charged only for the duration of the connection. Digital circuits or Digital Data Services (DDS) can carry data at 2.4, 4.8, 9.6, 19.2, 56, and 64Kbps. Digital circuits are not technically voice-grade, but they can be used to carry either voice or data. Slow speed leased lines have been used extensively by utilities to provide quick connections to various facilities and devices that cannot otherwise be reached in a structured network or telecommunications scheme.	http://www2.rad.com/networks/1994/modems/modem.htm; http://www.techtutorials.info/hdmodems.html; http://www.rad.com/RADCnt/MediaServer/3656_ldv-2.pdf; http://www.vocal.com/data_sheets/v925.html
Digital Subscriber Line (DSL)	In use for many years	Asymmetric Digital Subscriber Line (ADSL) is the formal name for what is being commonly called Digital Subscriber Line (DSL). Its most common use is to connect residential telephone customers to the Internet. ADSL converts existing twisted-pair telephone lines into access paths for Plain Old Telephone System (POTS) voice telephone circuits plus simultaneous high speed data communications. ADSL transmits two separate data streams with much more bandwidth devoted to the downstream than upstream leg. ADSL has a range of downstream speeds depending on distance.	http://www.dslforum.org/; http://www.itu.int/publications/index.html

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Cable Modem	In use for many years	The CableLabs Cable Modem project, also known as Data Over Cable Service Interface Specification (DOCSIS), defines standard interface requirements for cable modems providing high-speed data distribution over cable television networks. CableLabs provides services to certify devices to this specification. The DOCSIS specification has been internationally standardized as ITU-T J.112. In Europe, both J.112 and a competing standard called EuroModem are used. The CableHome project has developed interface specifications to extend cable-based services to IP network devices within the home. The CableHome project builds on the DOCSIS connectivity specification to address issues such as device interoperability, user convenience, Quality of Service, and network management.	http://www.cablemodem.com
Fiber to the Home (FTTH)	Limited adoption, pilot systems under test	"Fiber to the Home (FTTH)" is a technology that provides a broadband fiber-optic connection to consumer sites. FTTH has been the "holy grail" of the telecommunications industry for decades now, promising nearly unlimited bandwidth to the home user. However, until recently the costs of installing that much fiber optic cable and the associated electronics have been prohibitive. Increases in the cost-effectiveness of electronics have helped, but the key enabler of FTTH is the Passive Optical Network (PON). PON technology permits a single fiber to be split up to 128 times without active electronic repeaters. This creates a point-to-multipoint network that does not require any electronics between the consumer premises and the central office. A few telcos have deployed point-to-point fiber networks to supply FTTH. Others have connected PONs to neighborhood data concentrators called Optical Network Units (ONUs), creating "Fiber to the Curb (FTTC)" systems that may use either copper or fiber for the last connection to the customer. However, such systems have inherently higher costs than a point-to-multipoint PON.	http://www.ftthcouncil.org – FTTH Council; http://www.metroethernetforum.org/EFMA.htm – Ethernet over First Mile Alliance; http://www.fsanweb.org – Full Service Access Network (creators of APON).
Paging networks	Worldwide Adoption	Paging networks are radio systems for delivering short messages from the telephone system or Internet to (and sometimes from) small remote, mobile terminals. Paging systems use a variety of technologies including microwave and satellite. Like cellular systems, virtually all of the paging networks use more than one transmitter. Unlike cellular systems, they usually rely on simulcast capability to blanket an area. Several transmitters must send the same message over a wide area using the same frequency. A system controller applies sophisticated scheduling algorithms to manage the frequency spectrum used by the system. Some paging standards exist, such as POCSAG, or ERMES in Europe, but many systems remain either proprietary or licensed. Fortunately, paging systems typically provide a variety of open standard gateways in and out of the system, including direct serial, dial-up, and email.	http://www.refreq.com/braddye/pager.html

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Radio Frequency Identification (RFID)	Early Adoption	RFID (radio frequency identification) is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person. RFID is coming into increasing use in industry as an alternative to the bar code. The advantage of RFID is that it does not require direct contact or line-of-sight scanning. An RFID system consists of three components: an antenna, transceiver (often combined into one reader) and a transponder (the tag). The antenna uses radio frequency waves to transmit a signal that activates the transponder. When activated, the tag transmits data back to the antenna. The data is used to notify a programmable logic controller that an action should occur.	http://www.usingrfid.com/
Multiple Address System Radio (MAS)	Broad utility deployment in US	A basic MAS radio link consists of a master radio transmitter/receiver unit and multiple remote radio transmitter/receiver units. A master unit can access or poll multiple units via a pair of transmit/receive frequencies. The master unit is set up ready to transmit and receive to keep delays from transmitter keying to a minimum. Each remote unit is set up in the listening mode until it is polled and made ready to transmit. Each remote unit has a unique address so no two units will try to answer the poll at the same time. This eliminates any contention among the remotes to transmit to the master. The frequency pair used by MAS is licensed by the FCC and the same pair can be re-used elsewhere in the system as long as it does not cause any interference. For difficult-to-reach locations due to topography or limitation of line-of-sight, the same MAS radio can be used as a repeater radio to allow signal transmission over or around large obstructions. MAS radio is the preferred communication medium and has been used widely by utilities for SCADA and DA systems.	http://www.micronetcom.com/mas.htm
Spread Spectrum Radio System	Available now	To avoid having to operate with allocated frequencies from the FCC, a different type of radio known as spread spectrum (SS) radio is used in point to multipoint radio systems. The configuration of the master and remote radios is exactly the same as that for the MAS. The only difference is that FCC Part 15 Rules allow these radios to operate without the need for a license in the 902-928MHz frequency band. To meet the FCC criteria, the radios must operate at low power and must continually hop over a range of frequencies (typically 64 or more), staying on one frequency only for a short fixed period (typically 250 ms). Special processing built into the radio allows the radio to recover data in its original format while continually changing frequencies.	http://www.conformity.com/; http://grouper.ieee.org/groups/802/11/main.html; http://www.sss-mag.com/ss.html
IPv4 Core Networking	Available now	The Internet Protocol version 4 (IPv4) is the original network layer for the Internet suite of protocols (RFC 791, STD0005). Its primary characteristics arise from the fact that the structure of its four-byte address space was originally intended to (and still does) provide some information on how a message should be routed. Addresses with the same prefix share a subnet and do not need to be forwarded; addresses with different prefixes must be forwarded elsewhere. This simple routing decision makes it easy to implement end devices.	http://www.isoc.org/ – Internet Society; http://www.ietf.org/ – Internet Engineering Task Force; http://www.iana.org/ – Internet Assigned Numbers Authority; http://www.rfc-editor.org/ – Request for Comments archive (standards documentation).

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IPv6 Core Networking	~3 Years	Internet Protocol IP version 6 (IPv6) [RFC 2460], developed by the Internet Area of IETF, is a new version of the Internet Protocol, designed as a successor to IP version 4 (IPv4) [RFC-791]. The primary changes are (i) extension of the IP address from 32 bytes (IPv4) to 128 bytes (IPv6) to enable more addressable nodes, (ii) flow labeling, (iii) header simplification, and (iv) more support for extensions and options. Support of security services such as message authentication and encryption is also required for any implementation of IPv6. Advantages/Strengths: IPv6 has increased address space and other advantages over IPv4. Disadvantages/Weaknesses: Because of the enormous investment in IPv4, and the limited additional benefits of IPv6, IPv6 has not yet been implemented widely, and not much progress has been made in convincing vendors of the need to convert from V4 to V6.	http://www.ipv6forum.com/
AGA-12 Cryptographic Protection of SCADA Communications General Recommendations	2 to 5 Years	The American Gas Association (AGA) represents almost 200 local utilities that deliver natural gas to homes in the USA. These utilities are part of the critical infrastructure and rely on SCADA networks to control the operations. AGA, in conjunction with the Gas Technology Institute (GTI) and other industry groups, created AGA 12 to develop cyber security standards and protocols for the industry. AGA 12 has taken a unique approach to focus on securing the communications link between field devices and the control servers or control center. While there certainly is a risk of data insertion and modification in the communication channel, it may not be the most likely or even easiest avenue of attack on a SCADA system. The first Technical Report, TR-1, defines an add-on encryption module that also could be integrated into an RTU or PLC.	http://www.aga.org
Virtual Private Groups (VPG) technology	Available now	Enables endpoint-to-endpoint encryption of network traffic that addresses the threat of malicious insiders, reduces external threats, enforces only authorized communications between organizational and other groups to prevent mistakes, and does not require a supporting Public Key Infrastructure, making it superior to VPNs.	Adventium Labs; http://adventiumlabs.org; Brian Isle, Brian.Isle@AdventiumLabs.org

Table 1: Integrated Communications

ADVANCED COMPONENTS

Table 2: Advanced Components

Advanced Components			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Current limiting conductor (CLiC)	2 Years	The CLiC distributed series impedance device is low cost ($15 to $30/kVAr), can remotely operate with preprogrammed logic at each CLiC device to inject or remove series impedance, can control the flow of power, is modular, is coupled to the line at a transmission or subtransmission tower, is a commoditized module and could balance the flow between phases and between parallel lines thus reducing transients and maximizing use of T&D assets. This device is being tested at 161 kV by TVA at IPIC.	http://www.ipic.gatech.edu/research.html
Distributed series impedance (DSI)	3 to 4 Years	The "Smart Wires" distributed series impedance device is low cost ($20 to $40/kVAr), can inject or remove series impedance, can control the flow of power either with wireless or PLC, is modular, is coupled to the line at a transmission or subtransmission tower, is a commoditized module and can balance the flow between phases and between parallel lines thus reducing transients and maximizing use of T&D assets. It can also monitor line conditions such as thermal rating, vibrations, icing, etc.	http://www.ipic.gatech.edu/research.html, GATECH Intelligent Power Infrastructure Consortia (IPIC)
Improved HVAC bundle designs for lowering impedance and EMF (>345 kV)	1 Year	Tennessee Technology University did an electromagnetic field study in the late 1990s for TVA to design bundle configurations that can reduce EMF in >500 kV lines that are optimized and more compact using additional lines (like 4 X 5 X 4 versus the current 3 X 3 X 3 configuration). They found that the line impedance can be reduced by 50%, ATC increases by 50%, and EMF decreases by 70%. The switching surge safety is reduced however. A report was completed for TVA in the late 1990s that reviewed Russian low impedance and low EMF designs and developed new designs for possible use by TVA.	Tennessee Technology University
HTS Synchronous Condenser– SuperVARtm with 1G BiISSCO HTS wire	Available now	In shunt, SuperVARtm can provide low cost, distributed, small, modular dynamic reactive power compensation at about $100/kVAr with 2X peak output instantaneously and up to 2 minutes with exciter action with no harmonics. The SuperVARtm connects directly to the distribution system at 4.15 kV to 13.8 kV without a transformer. Current commercial units are 12 MVAr in size. In series it could provide dynamic, moderate cost power flow control. SuperVARtm has the potential to be >99% reliable with only 1.5% losses. TVA is installing two 12 MVAr SuperVARstm at one of their industrial customer's sites to provide improved power quality, flicker control, system voltage support, and short term ride through. The 8 MVAr SuperVARstm at TVA was successfully demonstrated for a year and then was decommissioned.	http://www.amsuper.com/products/motorsGenerators/index.cfm

Advanced Components			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
HTS Synchronous Condenser–SuperVAR with 2G YBCO HTS wire	3 to 6 Years	In shunt, High Temperature Superconducting Synchronous Condensers (HTSCC) with 2G wire can provide even lower cost voltage support than 1G SuperVARtm. It also can provide distributed, small, modular dynamic reactive power compensation with 2X to 4X peak output for short periods of time without harmonics. In series it can provide dynamic, moderate cost power control. The 2G system should be able to provide higher output at lower cost than a 1G system as the 2G system could be all superconducting with a low loss filamentized 2G wire state instead of a copper stator. The 2G SuperVARtm has the potential to be >99% reliable with only 0.5% losses.	http://www.ornl.gov/sci/htsc/publications.htm
HTS fault current limiters (FCL) using 2G wire	3 to 6 Years	2G wire FCLs can be developed that have 10X less AC losses, are instantaneous, limit currents by 3X to 10X, and have small footprints.	AMSC, SuperPower; http://www.ornl.gov/sci/htsc/publications.htm; SC Power Systems, Inc. (http://www.scpowersystems.com)
Short Circuit Current Limiter–Siemens' SCCL	Available now	Siemens has a Short Circuit Current Limiter (SCCL) that uses thyrister switches to bypass a series capacitor that is tuned with a series reactor to throw the series reactor into the circuit to reduce fault currents.	https://www.energy-portal.siemens.com/static/de/de/products_solutions/12793_106977_short%20circuit%20current%20limitation%20sccl.html
Flow control using HTS Cable	Available now	Very low impedance (VLI) circuit that, with a small, low cost 5% Phase angle regulator (PAR), can relieve congestion on parallel circuits and control the power flows within a network.	http://www.amsuper.com/products/transmissionGrid/104273030481.cfm
D-VAR or DSTATCOM	Available now	D-VARs or DSTATCOMs are mobile, relocatable, use insulated gate bipolar transistors (IGBTs) that are air cooled and operate at high efficiency resulting in low harmonics. They can be sited at T&D interfaces or at an industrial interface to provide voltage support, reduce industrial flicker generation, provide improved power quality, mitigate wind generator impact on transmission lines, etc.	http://www.amsuper.com/products/transmissionGrid/104273030481.cfm; http://www.sandc.com/products/purewave/dstatcom.asp
STATCOM	Available now	Static shunt compensator for dynamic voltage support in 1/4 cycle. Typical costs can range from $55/+-kVAr to $150/+-kVAr depending on level of redundancy and reliability required. SDG&E has installed a Mitsubishi STATCOM.	Mitsubishi, Siemens, ABB, Areva, http://www.eere.energy.gov/de/facts.html; http://library.abb.com/GLOBAL/SCOT/scot235.nsf/VerityDisplay/4EDF68B14B79751F85256C550053D6B6/$File/Hard-to%20Find%2019c.pdf
Static Synchronous Series Compensator (SSSC)	Available now	The SSSC is a solid-state voltage source inverter connected in series with the transmission line through an insertion transformer. This connection allows the SSSC to precisely control power flow in the line under a wide range of system conditions.	http://ece.umr.edu/
Solid State Transfer (SSTs) switches	Available now	SSTs are available now to provide customers uninterruptible power from two independent feeders.	http://library.abb.com/GLOBAL/SCOT/scot235.nsf/VerityDisplay/4EDF68B14B79751F85256C550053D6B6/$File/Hard-to%20Find%2019c.pdf on page 18

Advanced Components			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Utility Transformers with Phase Angle and Amplitude Control	5 to 7 Years	GATECH's IPIC has developed a concept that is ready to be demonstrated that can control voltage phase angle and amplitude to provide low cost power flow control. This concept can augment existing transformers, especially tap changing transformers, using a small power electronic converter with no energy storage. This approach provides simultaneous voltage regulation and phase-angle control, with graceful degradation as failures occur.	http://www.ipic.gatech.edu/research.html
SiC ETO based solid state transformer	5 to 7 Years	SiC ETO transformer at medium voltage would have no transformer oil and could generate VARs as needed.	http://www.spec.ncsu.edu/
Annealed Aluminum Steel Support (ACSS) with trapezoidal wire (TW) or ACSS/TW	Available now	Annealed aluminum steel supported with trapezoid cross section conductor wire (ACSS/TW) can carry 32% more current, reduce line losses at normal loads, and can be handled as normal ACSR conductor wire.	General Cable, http://www.southwire.com/welcome.jsp
Composite Conductors	1 to 2 Years	3M Aluminum Conductor Composite Reinforced (ACCR) costs from 5X to 8X ACSR conductor, but can increase transmission thermal capacity up to 85%. CTC's Aluminum Conductor Composite Core (ACCC) configured with trapezoidal wire is expected to cost 3X to 5X with a >55% capacity increase.	3M, CTC, http://www.southwire.com/welcome.jsp
Southwire annealed Aluminum Conductor Steel Supported (ACSS) Trapezoidal Wire (TW) with high strength steel (HS) at 285 ksi Tensile strength	Available Now	Southwire annealed Aluminum Conductor Steel Supported (ACSS) Trapezoidal Wire (TW) with high strength steel (HS) at 285 ksi Tensile strength can carry 62% more current, reduce line losses at normal loads, and can be handled as normal ACSR conductor wire. It is slightly more expensive than normal ACSR wire. It is slightly higher in weight, combines the attributes of the proven ACSS and ACSS/TW with a higher strength core for optimal performance, and provides good value for re-conductoring. It is made from extra high strength zinc-5% aluminum mischmetal alloy coated high carbon steel core material (Galfan). It utilizes existing steel knowledge resulting in high tensile strength without loss of elongation, ductility, or stress corrosion properties.	http://www.southwire.com/welcome.jsp
1G HTS cables	2 to 3 Years	HTS cables for MVDC applications can be used to transmit large quantities of power at reduced voltages (lower voltages reduce HVDC terminal costs by 25% to 50%) and high currents underground or undersea with no loss. Very low heat release allows small trenching requirements. HTS MVDC cables can reduce urban transmission congestion or allow for more intensive urban development. It allows offshore, high capacity factor, economic wind generators. It may be competitive with UG cables using large quantities of high priced copper.	http://www.ornl.gov/sci/htsc/publications.htm; http://www.amsuper.com/products/htsWire/HTSCables.cfm; https://www.energy-portal.siemens.com/irj/portal/ptd/public/en/global-01/home_ext
2G HTS cables	3 to 5 Years	6 times higher critical densities can be achieved with 2G wire versus 1G wire while operating at liquid nitrogen temperatures, and higher magnetic fields. Low AC loss can be demonstrated with filamentized 2G wire. Prices for 2G wire could be 3X to 10X cheaper than 1G wire and have 10X lower AC losses.	http://www.ornl.gov/sci/htsc/publications.htm; http://www.amsuper.com/products/htsWire/HTSCables.cfm; https://www.energy-portal.siemens.com/irj/portal/ptd/public/en/global-01/home_ext

Advanced Components			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
IntelliRupter® PulseCloser	Available now	To test for faults, PulseClosing applies a very fast, low-energy pulse to the line significantly reducing damaging fault currents and voltage sags on the faulted line as well as adjacent feeders. Substation transformers will experience fewer through-faults, extending their life. Cables, overhead conductors, splices, and terminations will also experience less thermal and mechanical stress from through-fault currents as well.	http://www.sandc.com/products/intellirupter/default.asp
Advanced OLTC for transformers	1 to 2 Years	Conventional tap changers are designed to keep the voltage on the low voltage side within certain limits around the set point. When the transmission side voltage decreases, traditional on-load tap changers adjust the output and draw more reactive power from the weakened transmission system. Intelligent on-load tap changers use both HV and LV values and perform an advanced tap changing control.	http://library.abb.com/GLOBAL/SCOT/SCOT296.nsf/VerityDisplay/166B5FE3F7459549C12571160034E615/$File/SA2006-000024_A_en_Advanced_OLTC_Control_to_Counteract_Power_System_Voltage_Instability.pdf
FACTS dynamic brakes	Available now	A dynamic brake is used to rapidly extract energy from a system by inserting a shunt resistance into the network. Adding thyristor controls to the brake permits addition of control functions, such as on-line damping of unstable oscillations. BPA has installed a dynamic brake on their system.	http://certs.lbl.gov/ntgs/issue-6.pdf (pg F-38); http://phasors.pnl.gov/resources_standards/WAPS_WPRC04.pdf (pg. 21 & 22)
Unified Power Flow Controller	Available now	A STATCOM plus a static series synchronous Compensator (SSSC) for power flow control is a Unified Power Flow Controller (UPFC). It requires a very specialized series transformer for the SSSC operation. It can provide all dynamic voltage support, all power flow control, or a combination, but it is expensive. AEP has installed a 138 KV UPFC.	https://www.energy-portal.siemens.com/irj/portal/ptd/public/en/global-01/home_ext; http://www.eere.energy.gov/de/facts.html
Convertible Static Compensator (CSC)	Available now	This is a UPFC that also has an interline power flow controller for bypassing transmission congestion at a substation or interface. (Applied at NYPA's Marcy substation.)	https://www.energy-portal.siemens.com/irj/portal/ptd/public/en/global-01/home_ext; http://www.eere.energy.gov/de/facts.html
One Cycle Control controllers	Available now	One Cycle Control controllers deliver a paradigm shift in active 3-phase power conversion (no Digital Signal Processors and no software) that enables reduced complexity, rapid dynamic response, global stability, high reliability for FACTS (STATCOM, DSTATCOM, UPFC, UPQC), unity power factor active AC/DC converters, Active Power Filters (APFs), inverters, and advanced transformers. These devices are the size of a business card.	One-Cycle Control, Inc.; http://www.onecyclecontrol.com
Medium Voltage Static Transfer Switch (MVSTS)	Available now	The MVSTS is designed to provide a whole facility power outage and voltage sag protection as a low cost alternative to large industrial UPS systems when a dual distribution feeder service is available.	http://www.satcon.com/products/grid.html; https://www.energy-portal.siemens.com/irj/portal/ptd/public/en/global-01/home_ext; Areva, ABB, Mitsubishi, AMSC, S&C Electric
Advanced Emitter Turn Off Thyristor (ETO) switch	In R&D	SPEC is pursuing the advanced 4th generation Emitter Turn Off Thyristor (ETO) based on silicon and the 5th generation ETO based on SiC to improve power electronic device performance and reduce cost. A 4th generation ETO small distributed FACTS device is being designed for a 10 MVA distributed FACTS application (like flicker control for a BPA wind farm), for a static series synchronous compensator (SSSC) for power flow control, and for a power electronic transformer using 5th generation ETOs based on SiC.	NCSU Semiconductor Power Electronics Center (SPEC), Dr. Alex Huang, aqhuang@ncsu.edu

Advanced Components			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Advanced Materials	In R&D	Advanced materials research is being done in various areas including: chemical vapor deposition of diamond tips in a vacuum to create a field effect transistor (DVFET) with 10 times voltage and current capabilities and capable of operating at 500 C, use of nano-diamond powder with transformer oil to increase oil thermal conductivity and transformer ratings, use of electrically doped diamond dust with copper and tungsten sintered to make erosion resistant and high temperature circuit breaker contacts and transformer load tap changers for voltage regulating transformers.	Vanderbilt University, Dr. Jim Davidson, jld@vuse.vanderbilt.edu
Medium Voltage Static Voltage Regulator (MVSVR)	Available now	The MVSVR boosts the whole-facility load voltage during source voltage sags caused by faults in the utility distribution grid or in the transmission system. The load voltage boost is performed within a quarter to half cycle enabling even the most sensitive facility equipment to ride-through sag events without operational disruptions.	http://www.satcon.com/products/grid.html; https://www.energy-portal.siemens.com/irj/portal/ptd/public/en/global-01/home_ext; Areva, ABB, Mitsubishi, AMSC, S&C Electric
Thyristor Controlled Series Compensators (TCSC)	Available now	Thyristor controlled series compensators (TCSCs) are an extension of conventional series capacitors by adding a thyristor-controlled reactor. Placing a controlled reactor in parallel with a series capacitor enables a continuous and rapidly variable series compensation system. The main benefits of TCSCs are increased energy transfer, dampening of power oscillations, dampening of subsynchronous resonances, and control of line power flow.	http://www.worldbank.org/html/fpd/em/transmission/facts_siemens.pdf; ABB, AREVA, Mitsubishi, etc.
Static Var Compensator (SVC)	Available now	Static Var Compensators (SVC's), the most important FACTS devices, have been used for a number of years to improve transmission line economics by resolving dynamic voltage problems. Their accuracy, availability and fast response enable SVC's to provide high performance steady state and transient voltage control compared with classical shunt compensation. SVC's are also used to dampen power swings, improve transient stability, and reduce system losses by optimizing reactive power control.	http://www.worldbank.org/html/fpd/em/transmission/facts_siemens.pdf, ABB, AREVA, Mitsubishi, etc.
Plug-in Hybrid Electric Vehicle	2 to 5 Years	While it appears that PHEVs are much better suited for short-term ancillary services such as regulation and spinning reserve, a large fleet of PHEVs could possibly replace a moderate fraction (perhaps up to 25 percent) of conventional low-capacity factor (rarely used) generation for periods of extreme demand or system emergencies. Overall, the ability to schedule both charging and very limited discharging of PHEVs could significantly increase power system utilization.	Technical Report NREL/TP-620-40293
EESTOR	1 to 2 Years	EESTOR has developed an advanced barium titanate energy storage device based on circuit film technology. The target market is batteries for hybrid electric vehicles, but it can be built for cell phones and in sizes up to 52 kwh. It can quickly charge and discharge in 15 minutes, and can cycle over a million times. The future vision would be plug in hybrids charging up during off-peak periods to increase loads and then be managed by intelligent agents or the transmission dispatch center to discharge into the distribution system (when hooked up) during emergencies or during high cost peak periods.	http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=7033406.PN.&OS=PN/7033406&RS=PN/7033406
NaS batteries	Available now	NaS batteries are now available for up to 8 hours for about $3500/kw for load following and peak shaving and can be used for voltage and transient stability support and customer ride-through. Shaving the peak can avoid need for new substations or second transformer banks.	http://www.vrbpower.com/, with 995 SI sq m needed per 10 MWs for 8 hours.

Advanced Components			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Vanadium Redox Flow batteries (VRB)	Available now	VRB flow batteries capable of 8 hours of storage are available now in small sizes for $2800/kw for load following, peak shaving, and frequency regulation and can be used for voltage and transient stability support and customer ride-through. Shaving the peak can avoid need for new substations or second transformer banks. An issue with VRB is the low power density of the electrolyte and the space requirements.	http://www.electricitystorage.org/tech/technologies_technologies_psb.htm, VRB Power Systems, Inc.; htttp//www.vrbpower.com
25 kWh Beacon flywheel	1 to 2 Years	Beacon 25kWh flywheels can be used for voltage and transient stability support and customer ride-through. Projected cost is $1000/ kw-15 minutes. Applications include frequency regulation, angular instability control and ramp mitigation.	http://www.beaconpower.com/products/EnergyStorageSystems/SmartEnergy25kWh.htm; http://www.beaconpower.com/products/EnergyStorageSystems/SmartEnergyMatrix.htm
Grid Friendly Appliances (GFA)	1 to 3 Years	Grid Friendly Appliances (GFA) mount in household appliances and are sensitive to change in frequency and voltage. They can be configured to take autonomous control or can be dispatched. Implementing controllable GFA's could be a low cost solution to mitigate system collapse and blackouts.	http://availabletechnologies.pnl.gov/infotechenergy/grid.stm
Thermal Energy Storage	Available now	Off-peak electricity can be used to make ice from water, and the ice can be stored until the next day when it is used to cool either the air in a large building (thereby shifting that demand off-peak) or the intake air of a combustion gas turbine generator (thereby increasing the on-peak generation capacity).	http://www.energy.ca.gov/distgen/equipment/energy_storage/energy_storage.html
Hybrid DER	3 to 5 Years	Hybrid DER (e.g., Solid oxide fuel cell combined with a microturbine) is expected to be less costly {$1200/kw to $1500/kw} than a fuel cell {$3,000/kw to $4,000/kw} and more expensive than the microturbine {$900/kw to $1,000/kw}, but can achieve efficiencies of 65% to 80% or more.	http://www.energy.ca.gov/distgen/equipment/energy_storage/energy_storage.html; http://www.eere.energy.gov/de/, Siemens, Fuel Cell Energy, etc.
Multiple DG types	Available now	Various types of Distributed Generation exist today.	http://www.distributed-generation.com/
Microgrids	1 to 2 Years	Microgrids are an application of distributed energy (DE) devices and control systems that enable a set of generators, storage devices and load-reduction technologies to reliably supply the entire electricity demand of a grid-isolated group of customers.	http://www.eere.energy.gov/de/minigrids.html
Power parks	Available now	Power parks (also called "premium power parks") are an alternative to the traditional approach. They may include uninterruptible power supplies such as battery banks, ultracapacitors, or flywheels. They typically include an on-site power source to increase reliability.	http://www.eere.energy.gov/de/power_parks.html
DC Microgrid	3 to 5 Years	Another concept for future power grids is to set up neighborhoods that run entirely on direct current (DC). A DC line would interface with the rest of the grid through DC-to-AC converters.	http://www.eere.energy.gov/de/dc_microgrids.html
Electric Load as a Reliability Resource	Available now	The use of normally passive loads to act as dynamic resources is a method for managing system reliability. Demand response applications controlled by system operators is an example of this.	http://www.eere.energy.gov/de/electrical_load.html

Advanced Components			
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Microgrid Fast Switch	2 to 3 Years	The Microgrid Fast Switch enables fast intentional islanding and automatic re-synchronization, but is a high cost today.	http://der.lbl.gov/seminars/ChrisMarnay021203.pdf
Customer-based DER	Available now	Some examples of customer based DER include plug-in hybrid electric vehicles (PHEV), fuel cells, integrated load control, grid-friendly appliances, etc.	Generic
Demand Response Business Network (DRBizNet)	Available now	This is an integrated infrastructure for DR that can be implemented in a distributed manner and drastically increase performance of DR business processes.	Utility Integration Solutions, Inc.; http://www.uisol.com
Island Renewables	3 to 5 Years	This technology focus includes Renewable DE (wind, solar, geothermal, ocean – hydrogen, thermal, waves), Bulk energy storage (batteries, hydro), Hydrogen Storage, and Biomass Technology.	Hawaii Distributed Energy Resources Technologies for Energy Security
DER Characterization	3 to 5 Years	This project involves the development and investigation of a power grid test bed in Playas, NM for grid modeling and DE characterization. Research will characterize distributed energy resources in terms of their capacity to reliably serve disparate local loads and support the performance of the grid. Specific research will be conducted in the following areas: synthesis of catalytic membranes for the conversion of sugars and alcohols to hydrogen (biomass), development of composite membranes for high temperature CO2/H2 separations, and methods for manufacturing low-cost photovoltaics.	http://www.nmt.edu/research/index.htm; New Mexico Tech Power Grid Reliability and Renewable Energy Research
High Power Lab	1 to 3 Years	The project is a feasibility study that will research, engineer, and demonstrate high-power laboratory testing protocols to accurately reproduce the conditions on the electric power grid representing both normal load switching and abnormalities such as short-circuit fault protection. Test circuits, equipment, and techniques will be developed and proven at reduced power levels to determine the feasibility of building a large-scale high-power testing laboratory. The project will deliver demonstrated testing techniques, high-voltage test equipment for load and simulation testing, and recommended designs for future implementation of a high-power testing laboratory to test equipment and systems to simulate the transmission grid (230kv).	http://www.sandc.com/
Variable Frequency Transformer (VFT)	Available now	The variable frequency transformer (VFT) is a controllable, bidirectional transmission device that can transfer power between asynchronous networks. Functionally, the VFT is similar to a back-to-back HVDC converter.	http://www.gepower.com/prod_serv/products/transformers_vft/en/variable_frequency.htm

Table 2: Advanced Components

ADVANCED CONTROL METHODS

Table 3: Advanced Control Methods

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Distributed intelligent control systems (multi-agents)	Available now	In computer science, a multi-agent system (MAS) is a system composed of several agents, capable of reaching goals that are difficult to achieve by an individual system.	An Introduction to Multi-Agent Systems, Wooldridge, Michael, John Wiley and Sons, 2002; http://dsonline.computer.org/portal/site/dsonline/menuitem.20d6846e1c7ed783f1a516106bbe36ec/index.jsp?&pName=dso_level1_home&path=dsonline/content&file=about.xml&xsl=generic.xsl; http://www.multiagent.com/
Distributed intelligent control systems (agents)	> 1 Year	Distributed intelligent control systems (agents) are adaptive, self-aware, self-healing, and semi-autonomous control systems using parallel and distributed processing. Distributed computing is parallel computing using multiple independent computers communicating over a network to accomplish a common objective or task.	http://www.infotility.com/; http://www.ieee.org/portal/site; http://www.computer.org/portal/site/transactions/menuitem.a66ec5ba52117764cfe79d108bcd45f3/index.jsp?&pName=tpds_home/about.htm&
Substation Automation (SA)	Available now	SA is the integration of smart sensors with integrated communication technologies to enable real time monitoring and control of substation equipment.	Vendor sites
Advanced SCADA	Available now	Advanced Control System's PRISM SCADA integrates additional functions to standard SCADA such as tagging, alarms, advanced user interface, load management, and short term load forecasting.	http://www.acsatlanta.com/
SMP Gateway	Available now	SMP Gateway is an advanced substation gateway that implements all the functions required for device integration at the substation-level: protocol converter, data concentrator, terminal server, automation processor and time synchronization.	Cybectec Inc.; http://www.cybectec.com
Distribution Automation (DA)	Available now	DA is the integration of smart sensors with integrated communications technologies to provide real time reconfiguration of distribution equipment to prevent customer outages and minimize time of disruption.	Vendor sites
Transmission Fast Simulation and Modeling (T-FSM) – Intelligrid	> 3 Years	The EPRI Intelligrid T-SFM system is based on a high performance distributed autonomous real-time control system using the latest available technologies. The plan is to embed intelligent devices to enable improved monitoring and control through innovations in prediction, sensing, modeling, analysis and optimization using wireless sensors, new PMUS, etc. The architecture for a distributed autonomous real-time (DART) has been developed.	http://www.epriweb.com/public/000000000001012148.pdf; Transmission Fast Simulation Modeling (T-FSM)-Architectural requirements EPRI report 1011667, March 2005.

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Waveform Analysis (Power Quality, etc.)	> 1 Year	This task will provide a state-of-the-art assessment of standards and current technologies being used for advanced monitoring systems, fault location, fault prediction, and fault analysis. Important assessments will include the following: Standards for sharing monitoring data (PQDIF, Comtrade, other), capabilities of different monitoring system platforms, sensor technologies and application; database designs for managing power quality and waveform data, systems integration of monitoring data with other information systems needed (electrical data, operations, SCADA, outage management, customer information, work management, asset management, etc.); and State-of-the-art fault location, prediction, and analysis. The deliverable for this task will be a report on the state-of-the-art in the areas listed above along with recommended priorities for development and implementation in the project.	DOE Funding Opportunity Number DE-PS02-05CH11270, Topic Area 3, "Development and Demonstration of Advanced Monitoring Systems for Fault Location, Analysis, and Prediction."
GE- ENMAC System	Available now	This system allows control room operators to view real-time measurements on the network, and perform remote telecontrol operations combined with front-end data processing. The ENMAC system integrates customer outages with up-to-date status of the distribution network, providing accurate information to customers concerning the status of power interruptions.	http://www.gepower.com/prod_serv/products/scada_software/en/enmac.htm
Areva - BiTRONICS 70 Series Real-time Monitoring and Event Recording	Available now	The BiTRONICS 70 Series Measurement System is a substation automation solution designed to satisfy the real-time monitoring and event recording needs of AC network operators. The BiTRONICS 70 Series Measurement System consists of four component types. These components form a real-time monitoring and event recording system for use in high voltage AC substations. The component types are monitoring and recording IEDs, detached displays, firmware, and software.	http://www.areva-td.com/static/html/TDE-AGF_Product-Product_Detail1_1097584055726.html?&static=yes&famid=1027433669789&typid=1027433669817&productline=1080218386776
Alstom ESCA	Available now	The CBWatch-2 continuously monitors circuit breaker condition. It signals in real time any malfunction to maintenance services. The CBWatch-2 reduces maintenance cost and failure risk.	http://www.areva-td.com/static/html/TDE-AGF_Product-Product_Detail1_1034425540533.html?&static=yes&famid=1027064314296&typid=1027064314312&productline=1026742850138
Dynamic Security Assessment	Available now	On line technology that takes a snapshot of the system condition, performs comprehensive security assessments in near real time, and provides operators with warnings of abnormal situations as well as remedial measure recommendations.	"Implementation of Online Security Assessment", Lei Wang and Kip Morison, IEEE Power and Energy Magazine, September/October, 2006.
Grid Real-Time Performance Monitoring and Prediction Platform (Grid-3P)	Available now	The Grid Real-Time Performance Monitoring and Prediction Platform (Grid-3P) provides state of the art performance monitoring technology for managing today's electric grid. It measures frequency, voltage, congestion, market power. It saves data on abnormal operating patterns and predicts system response in near real time.	http://www.electricpowergroup.com/epg_grid3p.html
HIQgrid Digital Control System	Available now	The HIQgrid Digital Control System is a flexible monitoring and control system that can be adapted to any energized equipment. It connects devices from different systems (like distribution transformers, streetlights, etc.) to a common control interface. The system is scalable up to hundreds of thousands of control points.	http://www.magnetekpower.com/pegproductshiqgrid.htm

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
D-FSM	> 3 Years	The Distribution Fast Simulation and Modeling Project helps operators control and optimize the grid in a safe reliable and quality way.	http://www.epri.com/IntelliGrid/FSM.html
CERTS Monitoring Applications based on Synchronized Phasor Measurements	In demonstration test	The major processes for the utilization of synchronized phase measurements are: data acquisition, post disturbance analysis, results analysis, model validation, and remediation planning, RAS threshold validation. All of these processes require an underlying communication network such as the Internet.	http://certs.lbl.gov/pdf/synphasor-appguide.pdf
GRIDSTAT	> 3 Years	GRIDSTAT is a flexible power grid communication architecture that provides a common service platform for disseminating power grid status information within and between power utilities, energy brokers, end-users and other participants. It allows input devices (publishers) to post or publish status information that will be available to grid monitors.	http://www.gridstat.net/; Microsoft Public Sector, Washington State University / PNNL; David E. Bakken, bakken@eecs.wsu.edu
Wide Area Measurement System (WAMS)	In service in the West	The Wide Area Measurement System, or WAMS, continuously monitors power grid performance and provides operators with high-quality data and analysis tools. Bonneville Power Administration, electric utilities and industry have collaborated to develop and implement this system across the Western power grid. It detects imminent grid emergencies, mitigates grid outages, improves analysis and control and enables dynamics analysis and modeling.	http://homeland-security.pnl.gov/cip.stm
The Grid Friendly Appliance™ Controller	Ready for licensing	The Grid Friendly Appliance controller developed at PNNL senses grid conditions by monitoring the frequency of the system and provides automatic demand response when needed. Within each of three vast interconnected areas of the North American power grid (East, West and Texas), a disturbance of the 60-Hz frequency is a universal indicator of serious imbalance between supply and demand that, if unarrested, leads to a blackout. This simple computer chip can be installed in household appliances and turn them off for a few minutes or even a few seconds to allow the grid to stabilize. The controllers can be programmed to autonomously react in fractions of a second when a disturbance is detected, whereas power plants take minutes to come up to speed. They can also be programmed to delay restart instead of all coming on at once after a power outage to ease power restoration.	http://gridwise.pnl.gov/technologies/transactive_controls.stm
Petri Net Analysis Applied to the Electric Systems	> 3 Years	PNNL scientists have been developing an advanced network analysis technique called Petri nets to help analyze the combined engineering and market aspects of the grid. They capture the underlying mathematics of the coupled models in a way that will provide insights into how the complexity of the system may be managed with existing computational machinery. Because the network connectivity and influences are largely pre-computed, they have the potential to allow exploration of both local and global control opportunities and their effects on the stability of the coupled systems in near real-time.	http://gridwise.pnl.gov/technologies/modeling_theory.stm

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Simulating the Combined Market and Physical Operations of our Electric Power System	> 3 Years	The vision for the simulation framework is to create an open source environment where independently developed software components can be shared by other people and organizations, and a variety of simulation environments can be configured to address analysis needs. This unique set of simulation tools will span energy systems currently analyzed in isolation—the transmission grid, distribution systems and customer systems (equipment and appliances)—and link their physical performance and control with the economic markets that will drive them in the future. Today's tools evaluate specific aspects of the system, and since they are not interconnected, it is very difficult to model the interactions of behaviors that are exogenous to a given tool. Yet, this very capability is required to understand the effect of GridWise solutions on our energy systems.	http://gridwise.pnl.gov/technologies/simulations.stm
DSOM® (Decision Support for Operations and Maintenance)	Available through PNNL	DSOM® (Decision Support for Operations and Maintenance) is a patent-pending expert O&M system that integrates plant operations, fuel management, and maintenance processes. DSOM is built around the concept of condition-based management. DSOM software collects and verifies operations data, analyzes them in a customized facility database and lets operators know, in real-time, if a system is malfunctioning or running below expectations. Beyond looking for early warning signs of problems, DSOM identifies conditions that could potentially lead to a problem, determines the root cause and prioritizes recommends solutions.	http://www.pnl.gov/dsom/
Enhanced Automation (EA)	Available now	Enhanced Automation (EA) adds weather, electricity prices and meter data to an energy management system to better control building costs, comfort and health.	http://www.energy.ca.gov/enhancedautomation/index.html
Distribution Asset Analysis Suite	Available now	By reconciling hourly SCADA data at the substation level with end-use customer and other sources of data, DAA Suite™ provides an engineering basis for predicting transformer loading and actual system-wide asset loads.	http://www.itron.com/pages/products_category.asp?id=itr_000390.xml
Smart maintenance	Available now	Smart maintenance is preventive maintenance, work orders, inventory, predictive maintenance, and maintenance requests all in one package.	http://www.smartwaregroup.com/landing.asp?code=google&kw=m-s
Center for Computational Learning Systems (CCLS)	Available now	CCLS has developed software that prioritizes system maintenance, provides real-time assessments of the failure susceptibility, real-time control, lean management of operations, and future grid design simulation, testing and validation. It also is providing software for analysis, design, operation, and control of electrical power systems and critical infrastructures that have interdependencies with electrical power systems. CCLS is working closely with Con Edison and EDD, Inc. - VT to field modernize grid functionality in NYC.	Columbia University, David Waltz, waltz@ccls.columbia.edu
Advanced Feeder Automation	Available now	Advanced Feeder Automation is an automatic power restoration system that uses distributed intelligence and peer-to-peer communication to switch and isolate the faulted line section and restore power to unfaulted line sections.	Vendor websites (S&C, ABB, GEPower, etc.)

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Automatic protective coordination after feeder reconfiguration	Available now	Protection coordination is automatically updated as circuits are reconfigured. Precision Curve Fitting algorithm automatically develops a protective curve that coordinates tightly with the substation breaker. Then, using high-speed propagation of information via the SpeedNet Radio system, time-current coordination settings of downstream IntelliRupters are set automatically. Automatic Protection Setup maximizes the number of IntelliRupters with unique time-current coordination settings. Communication-Enhanced Coordination ensures that only the last device feeding a faulted section clears the fault. The system allows to deploy an unlimited number of IntelliRupters for circuit segmentation.	http://www.sandc.com (IntelliTEAM III)
Transient Stability	Available now	Real-time phasor measurements and improved communication makes it possible to determine whether a transient swing in the power systems is stable or unstable.	"Real-time Stability in Power Systems" Edited by Savu C. Savulescu; http://ieeexplore.ieee.org/xpls/absprintf.jsp?arnumber=1610668
Real-time voltage stability	1 to 3 Years	The onset of voltage collapse point is calculated based on the load characteristics and Phasor Measurement Unit (PMU) measurements, and if the stability margin is small and the reactive power reserves nearly exhausted, then controls are deployed to steer the power system away from the critical point.	"Real-time Stability in Power Systems" Edited by Savu C. Savulescu; http://ieeexplore.ieee.org/xpls/absprintf.jsp?arnumber=1610668
Fault Locator for Distribution Systems	2 to 5 Years	Fault location using traveling waves has been applied in extra-high voltage power grids successfully. Due to its complication and high cost, it is not yet easy for this technique to be accepted for use in distribution systems. A new traveling wave fault location system is being developed in a cost-effective way for power networks (especially for distribution system). Two traveling wave sensors capture the current traveling wave flowing from the capacitive equipment to earth and the voltage traveling waves in all three phases.	Google search
Intelligent On-Load Tap Changers	2 to 5 Years	The tap changer is designed only to keep the voltage at the low voltage side within certain limits around the set point. When the transmission side voltage decreases, traditional on-load tap changers adjust the output and draw more reactive power from the weakened transmission system. Intelligent on-load tap changers use both HV and LV values and performs an advanced tap changing control.	http://library.abb.com/GLOBAL/SCOT/SCOT296.nsf/VerityDisplay/166B5FE3F7459549C12571160034E615/$File/SA2006-000024_A_en_Advanced_OLTC_Control_to_Counteract_Power_System_Voltage_Instability.pdf
Physical Operating Margin (POM) for ultrafast load flows with Boundary of Operating Region visualization tools	Available now	This technology performs ultrafast load flows (40,000 bus system solved in 0.5 seconds) and generates nomograms for operators showing regions of secure operations limited by voltage constraints, voltage instability, thermal limits, and flow gate constraints.	V&R Energy Systems Research, Inc.
Physical Operating Margin (POM) for ultrafast load flows with Optimal Mitigation Measures (OPM)	Available now	Optimal mitigation measures can be applied on-line to expand the boundary of the operating region defined by POM technologies to allow for reduced transmission congestion, optimal outage management, and optimal CAPEX planning.	V&R Energy Systems Research, Inc.

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Physical Operating Margin for transient stability analysis (POM/TS) accelerated with fast fault screening (FFS) algorithms with Optimal Mitigation Measures (OPM)	1 to 2 Years (in demonstration)	This technology when integrated with OPM can support CAPEX planning for minimal cost mitigation of transient instabilities, or in operations can mitigate potential transient instabilities.	V&R Energy Systems Research, Inc.
IntelliTeam - S&C Electric	Available now	This technology provides automatic restoration to the unfaulted section of the grid (without overloading components) using multi-agents to control protective devices and provide a reconfigured grid with fully coordinated protection.	S&C Electric; http://www.sandc.com
ROAMS System - Columbia University	Available now	This technology serves as a machine learning ranking engine whose aim is to produce a real-time list of the network's feeders sorted from most to least susceptible to failure. It is being applied on the ConEd system in collaboration with Virginia Tech.	Columbia University, Dave Waltz, waltz@ccls.columbia.edu
Distributed Energy Workstation	Available now	DEW (Distributed Engineering Workstation) creates integrated transmission-distribution system models that model every individual customer supplied by the grid.	Electrical Distribution Design (EDD), Virginia Tech, Robert Broadwater, dew@vt.edu
SensorBridge™	Available now	SensorBridge™ is a sensor system middleware product enabling rapid integration of sensor and actuator assets into existing data systems, including monitoring and control systems, and streamlined development of new sensor systems. Augusta Systems products support intelligent, sensor data filtering, processing, and communications on sensor processing systems at stations, substations, or among other grid equipment components.	Augusta Systems, Inc.; http://www.augustasystems.com
Self Improving Software Algorithms	> 1 Year	Self improving software learns from data that it is unfamiliar with it, and then adjusts itself to better handle the data. The key is that the algorithms learn from how the pieces of data fit within the range of possibilities, rather than having to learn the data's details.	Columbia University, Dave Waltz, waltz@ccls.columbia.edu
AGORA — Advanced Grid Observation Reliable Algorithms	Available now	AGORA — Advanced Grid Observation Reliable Algorithms validates the quality of real-time data and off-line system models. It graphically monitors and analyzes the state of the electric grid. It performs contingency analysis, clearance and outage requests. AGORA investigates, evaluates, and predicts how the system will respond if critical equipment is forced out of service. It automatically generates and proposes optimized plans for system restoration when presented with a large real-time or simulated system disturbance.	http://www.elequant.com/products/agora/
Weather and Load Forecasting - Artificial Neural Networks (ANNs)	Available now	An artificial neural network (ANN) is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation.	Columbia University, Dave Waltz, waltz@ccls.columbia.edu

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Weather and Load Forecasting - Fuzzy Logic	Available now	Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic.	http://web.cs.bgsu.edu/maner/wxsys/wxsys.htm
Weather and Load Forecasting - Numerical weather prediction (NWP)	Available now	Numerical weather prediction models are computer simulations of the atmosphere. They take the analysis as the starting point and evolve the state of the atmosphere forward in time using understanding of physics and fluid dynamics.	Weather Forecasting Handbook (5th Edition), Vasquez, T, 2002.
Weather and Load Forecasting - Ensemble forecasting	Available now	Ensemble forecasting uses numerous forecasts produced to reflect the uncertainty in the initial state of the atmosphere (due to errors in the observations and insufficient sampling). The uncertainty in the forecast can then be assessed by the range of different forecasts produced. They have been shown to be better at detecting the possibility of extreme events at long range.	http://www.cdc.noaa.gov/map/images/ens/ens.html
Weather and Load Forecasting - Nowcasting	> 1 Year	The forecasting of the weather in the 0-6 hour timeframe is often referred to as nowcasting. It is in this range that the human forecaster still has an advantage over computer NWP models.	http://www.rap.ucar.edu/projects/wsddm/bams.pdf
Integration with other Enterprise-wide processes and technologies using web services	Available now	The term Web services describes a standardized way of integrating Web-based applications using the XML, SOAP, WSDL and UDDI open standards over an Internet protocol backbone.	http://www.w3.org/TR/ws-arch/
Integration with other Enterprise-wide processes and technologies using Grid Computing	> 1 Year	Grid computing is an emerging computing model that provides the ability to perform higher throughput computing by taking advantage of many networked computers to model a virtual computer architecture that is able to distribute process execution across a parallel infrastructure.	http://www.gridforum.org/
Integration with other Enterprise-wide processes and technologies	> 3 Years	The Semantic Web is a project that intends to create a universal medium for information exchange by giving computer-understandable meaning (semantics) to the content of documents on the World Wide Web.	http://www.w3.org/2001/sw/Activity
Integration with other Enterprise-wide processes and technologies	> 1 Year	The efficient integration of new, real time operating information used by the Modern Grid with existing asset management and customer service processes and technologies. This integration is expected to dramatically increase the effectiveness and efficiency of these enterprise-wide programs.	http://www.sisconet.com/downloads/KnowUtil.pdf; http://uaelp.pennnet.com/Articles/Article_Display.cfm?Section=Articles&ARTICLE_ID=243625&VERSION_NUM=4&p=22

Advanced Control Methods			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Cleveland State Center for Research & Aerospace Technology	5 Years +	The underlying technology involves advancements in the fields of instruments, controls, and electronics. 1. Design of a distributed, fault–tolerant, and modular power system; 2. Develop the dynamics and control of active magnetic bearings for flywheel energy storage without using conventional sensors; and 3. Delivery of power through wireless systems (power beaming).	http://space-power.grc.nasa.gov; http://create.fennresearch.org/
Montana Tech Load Control System Reliability	3 to 5 Years	Research will focus on two areas: 1) real-time load control methodologies; and 2) measurement-based stability-assessment operation and control tools. Orientation is toward transmission applications. The technology research, development, and demonstration project proposed here is aimed at applying advancements in intelligent control and information technologies to the challenges of improved reliability of existing grid resources, load leveling of limited energy resources, and improved efficiency among systems of loads on a common grid.	http://www.mtech.edu/research/
WVU Integrated Controls (APERC)	3 to 5 Years	The initial focus will be on developing, testing and validating the performance of multi-agent system for controlling technical performance of a distribution feeder. The objective is to achieve robust, reliable multi-agent systems capable of maintaining and improving circuit stability through reduced fault vulnerability, fault tolerance and isolation, and rapid self-healing/correction of disturbances.	http://www.aperc.wvu.edu; West Virginia University, APERC, Ali Feliachi, alfeliachi@mail.wvu.edu
NETL Pilot Energy Cost Evaluation (Prologic)	Available Now	This demonstration / service project is designed to support several NETL buildings at the Morgantown, WV campus and will evaluate the cost savings associated with using existing commercial-off-the-shelf (COTS) technology. The system will be installed to control indoor and outdoor lighting, and HVAC parameters for research laboratories, computer centers, and other vital facilities at the NETL campus.	http://www.profile-systems.com/ (P1800 system)
Grid Shock Absorber	3 to 5 Years	This concept is the reconfiguration of existing large interregional networks into sets of asynchronously operated sectors connected exclusively by links based on new DC technologies. It is believed that such DC aided segmentation would minimize and possibly eliminate system stability issues and improve the control of power flow among sectors under both normal and emergency conditions.	EPRI Journal - Spring 2007, Aty Edris (aedris@epri.com)

Table 3: Advanced Control Methods

SENSING AND MEASUREMENT

Table 4: Sensing and Measurement

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Wireless, intelligent system sensors for condition information	> 5 Years	An ad-hoc (or "spontaneous") network is a local area network or other small network, especially one with wireless or temporary plug-in connections, in which some of the network devices are part of the network only for the duration of a communications session or, in the case of mobile or portable devices, while in some close proximity to the rest of the network. This would allow for integration of a computer enabled mobile workforce with field assets using GPS location stored in a GIS system. Gridsense LineTracker system is available to keep track of distribution line topology changes, fault location, and load monitoring.	http://w3.antd.nist.gov/wctg/manet/adhoclinks.html; http://www.ember.com/; http://www.gridsense.com.
Wireless, intelligent system sensors for condition information	Available now	Low cost wireless nodes that operate as intelligent radio devices (IRD) in a mesh network at 2.4 GHZ to 5.2 GHz with ranges up to 10 miles are available and can be added to various substation sensors (T, I2T, P, etc.) and lines (T, strain, stress, etc.). This IRD mesh could also be used with wireless nodes on towers in a mesh network for reliability for broadband communication. (Other 802.11g wireless Ethernet suppliers include MDS, Tropos, Vyvo, RadioLinx, and Cirronet.)	Intelicis, MDS, Vyvo, RadioNet, Cirronet
Wireless, intelligent system sensors for condition information	Available now	Low cost wireless nodes that operate as intelligent radio devices (IRD) in a mesh network on cellular systems based on 2nd or 3rd generation GSM or CDMA technologies at 0.8 GHZ to 1.9 GHz are available and can be added to various substation sensors (T, I2T, P, etc.) and lines (T, strain, stress, etc.). Suppliers of fielded cellular interface devices that include both serial and Ethernet type interfaces include I.P.S. Group, eLutions, and Telemetric.	http://ipsgroup.com/; http://www.elutions.biz/; http://telemetric.com/
Wireless, intelligent system sensors for operating information (MW, MVAR, Volts, Amps, PF, PQ, etc.)	> 5 Years	Another approach to low cost wireless nodes uses short range backscatter technology that harvests power to operate sensors (T, I2T, P, T, strain, stress, etc.); line sensing can employ helicopter data collection.	TVA
Wireless, intelligent system sensors for operating information (MW, MVAR, Volts, Amps, PF, PQ, etc.)	Available now	The I-Grid (www.i-grid.com) is an innovative and ground-breaking national web-based power disturbance monitoring and reporting system that was developed by SoftSwitching Technologies. With close to 1500 monitors installed nation-wide, I-Grid can provide analysis of events in almost any given region.	http://www.softswitch.com/sst/igrid.do

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Advanced instrument transformers	Available now	Fiberoptic PT and CT sensors and meters are available from NxtPhase (fiberoptic cables) and ABB (silicon crystals) that accurately measure voltage and current to revenue standards at any voltage over the entire range of the device. JDSU Photonic Power offers an optically powered CT sensor with up to 500 mW delivered to sensor head over multiplexed fiber optic link. Other vendors include Mitsubishi Electric and Hitachi/Toshiba.	http://www.nxtphase.com/; http://www.abb.com/; http://www.jdsu.com//; http://www.mitsubishi.com/; http://hitachi.com/; http://www.airak.com
Advanced instrument transformers	> 5 Years	The measurement system is composed of a current sensor and the associated electronics module. The current sensor includes an emitter, transmission structure and receiver. The magnetostrictive material of the emitter generates elastic (mechanical) waves under the alternate magnetic field induced by the primary current to be measured. Thus the 50 HZ, or 60 Hz, electrical signals are converted into elastic waves that propagate through a dielectric coupling structure until they reach the receiver. In the receiver side, the elastic waves are converted back into electrical signals.	European Commission IELAS project (Contract number G5RD-CT-2001-0054)
DONUT	Available now	DONUT is an advanced instrument platform designed for real time acquisition and data logging on high voltage overhead transmission systems.	Underground Systems, Inc.; http://www.usi-power.com
Advanced Signal Distribution	2 to 5 Years	Current and voltage measurements from instrument transformers are digitized, and these digital representations of voltage and current are distributed by network systems using either wire or fiber. This has the advantage of minimizing noise and interference in the secondary signals as well as the cost. The fundamental problem with this approach is creating a single digital measurement that is appropriate for all uses.	http://ieeexplore.ieee.org/xpls/absprintf.jsp?arnumber=1610668
Intelligent On-Load Tap Changers	2 to 5 Years	The conventional tap changer is designed to keep the voltage at the low voltage side within certain limits around the set point. When the transmission side voltage decreases, traditional on-load tap changers adjust the output and draw more reactive power from the weakened transmission system. Intelligent on-load tap changers use both HV and LV values and perform an advanced tap changing control. (Pilot development by Canadian Electric Association.)	http://library.abb.com/GLOBAL/SCOT/SCOT296.nsf/VerityDisplay/166B5FE3F7459549C12571160034E615/$File/SA2006-000024_A_en_Advanced_OLTC_Control_to_Counteract_Power_System_Voltage_Instability.pdf
Wide Area Protection	Available now	Real-time phasor measurements and improved communication makes it possible to determine whether a transient swing in the power system is stable or unstable.	"Real-time Stability in Power Systems" Edited by Savu C. Savulescu; http://ieeexplore.ieee.org/xpls/absprintf.jsp?arnumber=1610668
Wide Area Protection	2 to 5 Years	The voltage collapse point is calculated based on the load characteristics and Phasor Measurement Unit (PMU) measurements; if the stability margin is small and the reactive power reserves nearly exhausted, controls are deployed to steer the power system away from the critical point.	"Real-time Stability in Power Systems" Edited by Savu C. Savulescu; http://ieeexplore.ieee.org/xpls/absprintf.jsp?arnumber=1610668
WAMS	1 to 5 Years	WAMS uses synchronized phasor measurements that can stream data, in real time, to phasor data concentrator (PDC) units. PMU networks have been deployed at several utilities. The primary impediments are cost, reliability, and assuring value for the investment.	http://phasors.pnl.gov/

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
RFID	2 to 5 Years	Short for radio frequency identification, RFID is a technology similar in theory to bar code identification. With RFID, the electromagnetic or electrostatic coupling in the RF portion of the electromagnetic spectrum is used to transmit signals. It could be used with GIS system with pre-determined GPS position of electrical asset.	http://www.xbow.com/; http://www.rfidnews.org/
Fiber optic sensors	Available now	This new signal conditioner, designed for direct and real time measurement of hot spot monitoring for small and medium transformers, is intended for utilities concerned about safety and reliable operation of their high voltage equipment. The Nortech TT represents a significant development and cost reduction effort to meet the electric industry's ever-growing requirements in terms of monitoring.	http://www.fiso.com; http://luxtron.com/
Electromagnetic Sensors	Available now	Ultra low noise, low frequency electromagnetic sensing systems and services. EM sensing technology has been used for applications such as lightning detection, electrostatic hazard monitoring, and underground facility detection, and QFS is at the forefront of new areas like airborne and underwater electric and magnetic field sensing. (Collaborating with Genscape.)	QUASAR Federal Systems, Inc.; http://www.quasarusa.com
Dynamic Ratings (lines, components)	2 to 5 Years	Dynflo distributed series impedance devices on each phase on each tower can also measure line temperature and thus line sag. Dynamic ratings of transformers are being demonstrated at EKPC now.	Dr. Deepak Divan at Georgia Tech's Intelligent Power, Infrastructure Consortium (IPIC), http://www.ipic.gatech.edu/
Dynamic Ratings (lines, components)	2 to 5 Years	An alternative to video-based "sagometer" is to use differential GPS to directly measure sag. Differential GPS has been demonstrated to be accurate for use in measuring distances to within much less than half a meter. Also PowerDonut load cell measurement of sag has been developed and tested as part of PSERC demonstration program.	http://certs.lbl.gov/pdf/52047.pdf; http://www.pserc.org
Dynamic Ratings (lines, components)	2 to 5 Years	PSERC sponsored the development of the Visual Basic software program called Grandline that calculates line sag and current carrying capacity in real-time. It uses inputs from both direct and indirect measurements of wind and local temperature variables and GPS line sag or implied line sag from calculations.	http://www.pserc.org
Dynamic Ratings (lines, components)	2 to 3 Years	GATECH's IPIC plans to develop a wireless Sensornet for dynamic thermal rating of a line at a target cost of $200 per sensor. This would allow the sensing of thermal line rating for all spans which would eliminate the need to ID a critical span and the effects of micrometeorological effects like different local wind conditions.	Dr. Deepak Divan at Georgia Tech's Intelligent Power, Infrastructure Consortium (IPIC), http://www.ipic.gatech.edu/
Transformer Monitoring Systems	Available now	Sophisticated monitoring tools are now commercially available that combine several different temperature and current measurements to dynamically determine temperature hot spots in transformers.	vendor websites

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Transformer Monitoring Systems	Available now	Sophisticated transformer monitoring tools are now commercially available that measure dissolved gases-in-oil and predict the health of transformers and LTCs in real-time. They can be used to generate green-yellow-red condition for operators. Latest generation from Serveron extends previous EPRI work to develop a low cost solid-state gas-in-oil monitor. Extraction of gas sample from oil is used in commercially available field reliable gas chromatograph to give precise gas concentration measurements without the need for timely and costly oil sampling/lab analysis currently in use by utilities.	http://www.serveron.com
Circuit Breaker Monitoring Systems	Available now	CB real-time monitoring systems measure number of operations since last maintenance, operate times, oil or gas insulation levels, I2t energy, and breaker mechanism signatures. Monitors available from several sources including GE TM1800, ABB, and Siemens.	http://www.ge.com; http://www.abb.com/; http://siemens.com/index.jsp
Cable Monitoring Systems	Available now	Cable monitors help to determine changes in buried cable health by trending partial discharges or periodic impulse testing of monitored lines. Monitors include GE IDA 200, AVO CableTrend® and NetworkTrend®, KEMA and others.	http://www.ge.com; http://www.avobiddle.com/Products.htm; http://www.kema.com/
Battery Monitoring Systems	Available now	Batteries are used in substations and generation plants as auxiliary power when the grid power is unavailable. Batteries are a high maintenance item and advances in low cost monitoring help to minimize battery failures. Monitors can now check cell health, specific gravity, liquid level, cell voltage and charge/discharge characteristics. Vendors include Alber, Trimetric, Liebert, Xantrex, VictorEnergy and others.	http://alber.com/; http://liebert.com/; http://trimetric.com/; http://www.xantrex.com/; http://www.victronenergy.com/
I-Sense® power quality monitor, I-Grid® monitor system	Available now	These power quality monitoring devices can be used as part of a nation-wide electric power monitoring system.	SoftSwitching Technologies Corp.; http://www.softswitch.com
AEP Ultra-sonic transformer monitor	>2 Years	This sensor and analysis software can detect the high frequency electrical and audio noise associated with incipient arcing. The R&D effort is intended to ascertain the patterns and signatures associated with high energy versus low energy events and associating a signature with a component problem.	SoftSwitching Technologies Corp.; http://www.softswitch.com
Advanced Metering Infrastructure	Available now	AMI is a complete system that integrates advanced meters with an appropriate communication system to provide consumer consumption information and system status to energy providers. Advanced meters and the supporting infrastructure are available from a number of vendors including - AMDS, Amron, Badger Meter, Cannon Technologies, Cellnet, Comverge, DCSI, Elster, eMeter, ETG, GE, Hexagram, Hunt Technologies, Itron, Landys-Gyr, Nertec, Sensus Metering Systems, Silver Springs Networks, Smartsynch, Tantalus Systems, Telenectis, and Transdata.	Vendor websites
Consumer Portal	Available now	Gridpoint Protect is the size of a small file cabinet, connects to the circuit breaker panel and works in conjunction with dynamic pricing to manage energy consumption. In addition, the unit also stores electricity using gel style batteries.	http://www.gridpoint.com

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Consumer Portal	Available now	A consumer portal is a smart interface between the consumer and the energy provider. It will provide emerging information-based solutions that improve the efficiency, comfort and safety of businesses, buildings and homes and integrate with power delivery system applications.	http://www.broadbandenergynetworks.com/; http://www.mentorgen.com/index.php?option=com_content&task=view&id=57&Itemid=74
Consumer Portal	2 to 3 Years	Based on an open flexible architecture, the portal will facilitate the implementation of new services such as DR and real time pricing, outage detection, remote connect/disconnect, support to distribution operations, PQ monitoring and improved customer information.	http://www.epri-intelligrid.com/intelligrid/docs/1012028_Consumer_Portal_7.05.pdf
Consumer Portal	Zigbee: Available now. Z-Wave: Available in 2 to 3 Years	GoodWatt, a device from Invensys, has been demonstrated by BPA in their non-wires solution program at demand response implementations at Salem and Ashland, OR on several hundred customer sites. The customer monitors real-time energy usage and determines a control strategy in response to a critical peak price signal from BPA. GoodWatt acts as a gateway from the customer's utility meter to other controllable loads such as pool pumps, water heaters, and air conditioners. The portal uses the emerging industry RF standard Zigbee with chipsets from Cirronet. Other emerging solutions may be based upon an Intel backed RF home network solution called Z-Wave with chipsets from Zen-sys.	http://cirronet.com/zigbee.htm; http://zigbee.org/en/index.asp; http://www.z-wavealliance.org/modules/start/; http://www.zen-sys.com/
Consumer Portal	Available now	During times of economic or reliability stress on the power grid, utilities and grid operators need a quick, simple, and convenient way to alert customers. PG&E as part of both their demand bidding and critical peak pricing programs has deployed the Energy Orb from Ambient Devices that sits in the customer's lobby or facilities manager desk. A low powered device (3.5W), it changes colors depending upon the level of the system alert from blue to yellow to red. Communication to the device is by a radio signal dispatched by either the utility or grid operator.	http://www.pge.com/news/news_releases/q2_2006/060515.html
eMiner™	Available now	This technology acts as an interface for customer meters, building and process control systems and live market information. It can potentially serve as an energy management tool for load response which requires secure, reliable communications among meters, substation systems, generating assets, distributed generators, grid status and market prices data bases, and end-users building/process control systems. It has been implemented at 100 sites including commercial, industrial, substation, and generating asset applications.	WPS Resources Corporation – Applied Technology Group
Wireless ePulse	Available now	This technology provides data recording and communication for early detection and notification of failures. MTS Technologies' primary customers are the US military; however, they have also been involved in integration, diagnostics, security and simulation technologies to enhance the electric grid.	MTS Technologies, Inc.; http://www.mtstech.com

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Advanced Protection Systems	Available now	Advanced Protection Systems are intelligent electronic devices that sense power system operating conditions, perform calculations and analysis to determine the risk to assets and the grid, initiate high speed control actions to protect the assets and the system from damage, instability, and propagating outages, and provide near-instantaneous information to system operators via a local data acquisition device either wirelessly, optically, or via cable. Examples include Schweitzer type protective relaying devices, distribution automation and substation automation schemes, etc.	http://www.selinc.com/; http://www.basler.com/html/pcs700v.htm
Advanced Protective Relays	Available now	All current suppliers of advanced relays offer a complete line of technologies for the protection, monitoring, control, automation, and metering of electric power systems. Industry adoption of standard protocols has advanced to support both DNP3 and IEC 61850. Rapid adoptions of IEC standards by international utilities have accelerated. Advanced functions include integrated fault location, hi-z distribution fault detection, advanced transformer and bus fault detection algorithms, and use of network communication for advanced relaying.	http://selinc.com/; http://www.ge.com/en/; http://www.abb.com/; http://www.zivpmasc.com/; http://www.siemens.com; http://areva.com; http://baslerelectric.com/; http://beckwithelectric.com/
Advanced Overhead Line Protection	Available now	To test for faults, PulseClosing applies a very fast, low-energy pulse to the line—significantly reducing damaging fault currents and voltage sags on the faulted line as well as adjacent feeders. Substation transformers will experience fewer through-faults, extending their life. Cables, overhead conductors, splices, and terminations will experience less thermal and mechanical stress from through-fault currents.	http://www.sandc.com
Waveform Analysis	2 to 5 Years: Integration of FLIR with Outage Management and RF AMI systems	Fault location using traveling waves has been applied in extra-high voltage power grids successfully. Due to its complication and high cost, it is not yet easy for this technique to be accepted for use in distribution systems. A new traveling wave fault location system is being developed in a cost-effective way for power networks (especially for distribution system). Traveling wave sensors capture the current traveling wave flowing from the capacitive equipment to earth and the voltage traveling waves in all three phases. Advances in fault location are allowing utilities to reduce customer outage by quickly locating a fault, identifying its location, and dispatching available trouble crews and tracking the activity in an outage management system. The location of the fault can be independently verified by integration of data from an AMI meter reading system.	http://www.paper.edu.cn/scholar/download.jsp?file=zengxiangjun-18&title=Fault%20Location%20Using%20Traveling%20Wave%20for%20Power%20Networks
Special Protection Systems	Available now	Special Protection Systems, also known as remedial action schemes, allow grid operators to implement power transfers across the grid that under normal criteria, would not comply with N-1 or N-2 contingencies. Grid operators can load transmission lines closer to thermal limits beyond normally prudent voltage or system stability limits. The systems consist of real-time monitoring of key generation assets or transmission lines and the associated power flows. Upon change of status (loss of generation and/or loss of transmission line), a pre-programmed set of actions is performed (e.g. wide area load shed, generator redispatch, separation of interties or islanding). Each regional reliability organization sets rules for design and implementation along with NERC compliance (ERO) and IEEE Power Engineering Society PSRC standards body. Special Protection Systems and Remedial Action Schemes are in place today especially in West. Advanced use of SONET/VLAN/Ethernet communication schemes has been piloted.	http://www.wecc.biz/documents/2006/General/RAS_Guide_6-10_clean.pdf ; http://www.nerc.com/~filez/spctf.html; http://www.pes-psrc.org/; http://www.pes-psrc.org/Reports/Voltage%20Collapse%20Mitigation.pdf; http://www.pes-psrc.org/Reports/; http://www.spectrum.ieee.org/print/2407

Sensing and Measurement			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Electric Grid Monitoring (Genscape)	Available Now	R&D is underway at University of Louisville to develop low cost, rapidly deployable, self-powering transmission line monitors that relay line operational status from remote locations wirelessly. Measurement and monitoring (not connected) of power flow and direction originally designed for marketing purposes that may be useful for government, FERC and OE applications. Environmental power sources (acoustic, electromagnetic, radiofrequency, and vibration) suitable for scavenging in the transmission line environment will be researched for monitor sensors, processors or communication module operation.	Genscape Inc.; http://www.genscape.com.
NXEGEN Connecticut Demand Response Technologies	Available Now	NXEGEN Connecticut Demand Response Technologies demonstrate that real-time electricity metering, monitoring & non-intrusive load management can benefit the commercial / industrial markets. Activities will include: • Installation of Real-Time Wireless Metering & Monitoring. • Installation of automated & direct control systems.	http://www.nxegen.com/default.asp

Table 4: Sensing and Measurement

IMPROVED INTERFACES AND DECISION SUPPORT

Table 5: Improved Interfaces and Decision Support

Improved Interfaces and Decision Support			
Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Advanced Pattern Recognition	> 1 Year	Pattern recognition is also intrinsic to network intruder detection, forgery detection, biometrics, next-generation computer interfaces and automatic paraphrasing, translation and language understanding.	http://www.trnmag.com/mtfpatternrecognition.html
Real-time 3-D Visualization with Virtual Reality	> 1 Year	Supports power system simulation, analysis, decision support.	http://www.pserc.wisc.edu/
Virtual Machines	> 1 Year	A virtual machine is a self-contained operating environment, created by a software layer, that behaves as if it were a separate computer. Benefits of creating virtual machines include better exploitation of powerful computing resources and isolation of applications to prevent cross-corruption and improve security.	http://www.computerworld.com/softwaretopics/software/story/0,10801,110722,00.html?SKC=software-110722
Intelligent Alerting Systems	> 1 Year	Alerting systems to deliver alerts on business performance, supply chain alerts, customer activity, monitored date, metered data, etc.	http://www.microstrategy.com
Intelligent User Interfaces (e.g., MIT's Project Oxygen)	> 1 Year	The use of techniques from the field of autonomous agents provides a new complementary style of human-computer interaction, where the computer becomes an intelligent, active and personalized collaborator. Interface agents are computer programs that employ Artificial Intelligence methods to provide active assistance to a user of a particular computer application.	http://www.aaai.org/aitopics/html/interfaces.html; http://www.computerworld.com/softwaretopics/os/story/0,10801,73697,00.html
Region of Stability Existence (ROSE) using phasor measurement unit (PMU) data	1 to 2 Years (in demonstration)	Region of Stability Existence (ROSE) using phasor measurement data can be plotted for the operator on-line using PMU data in 1D or 2D space and show regions of secure operations limited by voltage constraints, voltage instability, thermal limits, and flow gate constraints. Optimal mitigation measures can be applied on-line to expand the ROSE.	V&R Energy Systems Research, Inc.
On-line Transient Stability Monitor using Fast Fault Screening	1 to 2 Years	This is a fast on-line transient stability monitor that uses fast fault screening to determine the most severe faults and an ultra-fast transient stability model by V&R Energy Systems Research (Physical Operating Margin (POM)-Transient Stability (TS)). With fast fault screening and input from a state estimator model, POM-TS can solve for transient stability limitations in under a minute. Eventually when Supervisory Control and Data Acquisition (SCADA) data is input, it will be able to monitor for transient instabilities on line.	http://www.vrenergy.com/

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Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
On-line Transmission Optimization software	Available now	A fast on-line transmission dispatch optimization model already exists and is in use at ATC, ConEd, and Idaho Power. In Thailand, V&R Energy Systems Research is implementing a real-time transmission dispatch optimization software. The software has been shown to be much more robust than other existing applications. It can reduce transmission congestion by optimizing generator MW and MVAr dispatch, capacitor and reactor settings, transformer load tap change settings, phase shifter settings, dynamic sources of reactive compensations, and take non-affected lines out of service, etc. The software not only can reduce transmission congestion, but is so fast, it can be used for optimum remedial action in the event of a contingency or an emergency.	http://www.vrenergy.com/
PowerWorld Simulator	Available now	PowerWorld is an extremely visual, high-voltage power system simulation and analysis package capable of efficiently performing power flow analysis on systems containing up to 100,000 buses.	http://www.powerworld.com/
Integrated Energy Operations (IEOC), PNNL to commission in April, 2006	1 to 2 Years	IEOC is a new user-based facility dedicated to energy and hydro power research, operations training and back-up resources for energy utilities and industry groups.	http://www.clarityvisual.com/news/pressroom/0602/0227_PNNL.asp, Washington State University / PNNL
Advanced Speech Recognition: Voice Activated Search Engine	> 1 Year	Speech recognition systems are composed of three major functions. First, words are captured and translated into a digital signal. Then a speech-recognition algorithm compares those signals to words and phrases from a pre-set dictionary. Finally, the software offers the most likely match for the spoken phrase. (Patent applied for.)	http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=/netahtml/search-adv.htm&r=1&p=1&f=G&l=50&d=ptxt&S1=7,027,987&OS=7,027,987&RS=7,027,987#top
Advanced Speech Recognition: Speech-to-Speech Translation	> 1 Year	The goal of the Speech-to-Speech Translation (S2S) research is to enable real-time, interpersonal communication via natural spoken language for people who do not share a common language. The Multilingual Automatic Speech-to-Speech Translator (MASTOR) system is the first S2S system that allows for bidirectional (English-Mandarin) free-form speech input and output.	http://domino.watson.ibm.com/comm/research.nsf/pages/r.uit.innovation.html; DARPA and IBM Research
Haptic Interfaces for control inputs through hand movements	> 1 Year	Haptic interfaces are devices that let users generate control input through hand movements and provide users with tactile and force feedback consistent with what the user is seeing. These systems permit users to sense and manipulate 3D virtual objects with respect to features such as shape, weight, surface textures and temperature. Haptic devices such as haptic gloves, joysticks, and tactile arrays have advanced rapidly and can generate a wide range of force and tactile feedback. These devices present the right tools for human-computer interaction researchers to develop haptic cueing/messaging systems and haptic spatial representation systems that integrate seamlessly with existing multimodal applications.	http://www.ieee.com; Massachusetts Institute of Technology; Research in progress (IEEE, DARPA, etc)

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Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
Integrated 3D Video Cards into visualization programs	Available Now	Today, AGEIA is dedicated to delivering dynamic interactive realism to the ever demanding complexity of next generation games. Its flagship solution, AGEIA PhysX, is the world's first dedicated physics engine and physics processor to bridge the gap between static virtual worlds and responsive unscripted physical reality. AGEIA PhysX allows developers to use active physics-based environments for a truly realistic entertainment experience. Technology is available today, but not integrated within utility-scale visualization programs. PhysX product using in the gaming industry has applications in combat training, robotics, etc.	http://www.ageia.com/about/index.html
Diffraction-Based Optical Crossbar Switch has Applications in Optical Networking, Holographic Video, and Optical Computation	> 1 Year	Actuality Systems' core product is the Perspecta platform, which consists of a unique 360-degree spatial display and the associated Perspecta software and SDK. The platform enables users to render high-resolution spatial images that can be viewed from any angle as the user moves around the display. The display itself illuminates a record 100 million volume pixels, or "voxels," within a transparent sphere. Typical applications for the Perspecta platform include: drug discovery, such as visualization of protein structures; surgical planning and radiation treatment planning for doctors working to understand the exact location of a tumor on a CAT scan or mammogram; air-traffic control; game development; security specialists seeking a faster and more reliable way to visualize the contents of freight or passenger luggage, and numerous other possibilities. (Patent awarded.)	http://www.actuality-systems.com/site/content/pr_beam_steering.html
GIS Map Displays with Spatial Analysis, Attribute Mapping, and Data Conversion	Available now	A geographical information system (GIS) is a system for creating and managing spatial data and associated attributes.	http://www.esri.com/; http://www.fgdc.gov/nsdi/nsdi.html; http://www.gita.org/; Intergraph Corporation
GIS 3-D with Virtual Reality Simulation and Modeling and 3-D Visualization	> 1 Year	Addition of 3-D with Virtual Reality Simulation and Modeling	http://www.esri.com/news/arcnews/summer04articles/virtual-reality.html
GIS 4-D Modeling with time	> 1 Year	Multi-Dimensional Presentation	http://skagit.meas.ncsu.edu/~helena/gmslab/viz/vol1.html; http://www.geo.informatik.uni-bonn.de/publications/2002/ACM_GIS02_paper.pdf

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Open GIS	2 to 5 Years	The vision of OpenGIS® is a world in which everyone benefits from geographic information and services made available across any network, application, or platform. Approximately 80% of business and government information has some reference to location, but until recently the power of geographic or spatial information and location has been underutilized as a vital resource for improving economic productivity, decision-making, and delivery of services. We are an increasingly distributed and mobile society. Our technologies, services, and information resources must be able to leverage location, (i.e., my geographic position right now) and the spatial information that helps us visualize and analyze situations geographically. Products and services that comply with OGC's open interface specifications enable users to freely exchange and apply spatial information, applications and services across networks, different platforms and products.	http://www.opengeospatial.org/ Open Geospatial Organization
Origin GIS	Available now	By using a spatial network connectivity database and levering an industry-leading GIS (geographic information system) mapping software, this tool gives you the information you need to manage your distribution assets.	http://www.itron.com/pages/products_category.asp?id=itr_000390.xml
GeoIQ™	Available now	This is a web-service application that supports geospatial analysis and visualization. These are available for innovative heat map visualization techniques that are well suited for use by non technical personnel and decision makers.	http://www.fortiusone.com
GE Smallworld	Available now	Provides scalable, extensible and open solutions that integrate with existing systems to leverage spatial data in new ways: throughout the enterprise and onto the Internet. It helps in understanding where customers are and the infrastructure through which products and services are delivered.	http://www.gepower.com/prod_serv/products/gis_software/en/index.htm
PowerWorld Retriever	Available now	Gives operators a real-time or historic view of the power system and its various parameters quickly, accurately, and in a format that increases situational awareness. Connects to external, real-time data sources to import and display real-time data.	http://powerworld.com/products/retriever.asp
CERTS VAR-Voltage Management Tool	Available Now	The CERTS VAR-Voltage Management Tool substitutes a visual, bird's-eye view of the overall health of the grid for difficult-to-read tables of voltages at each monitoring point within the electricity system. By mining, analyzing, and presenting operational data in an easy-to-understand visual format, this tool addresses a key problem facing operators today—data overload—and enables them too effectively and reliably maintain safe operating margins.	http://certs.lbl.gov/pdf/rt-var-summary.pdf
Genscape Power North America	Available Now	This is a web-based interactive map representing estimated, real-time power production and transmission flows for facilities monitored in the Continental US.	http://www.genscape.com/na/index.shtml

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Title	**Time to Market Use (yrs)**	**Brief Description from Cited Reference**	**References**
CERTS Area Control Error (ACE)-Frequency Real-Time Monitoring System	Available Now	The ACE tool uses data visualization techniques to assess compliance with NERC reliability rules for the 143 control areas in North America. The tool relies on data generated every four seconds by all control areas and creates a real-time visual display of the entire power grid. This display immediately alerts NERC Reliability Coordinators to emerging frequency abnormalities within an interconnection and can pinpoint the control areas causing the violations. Armed with this information, coordinators can initiate corrective actions within minutes to prevent further degradation of system reliability.	http://certs.lbl.gov/pdf/ace.pdf
CORA, EOOS Plant Monitoring Tools	Available Now	Plant monitoring software systems that include the Control Room Automation (CORA) Suite and the EOOS Risk Monitor integrate seamlessly into an existing environment and quickly become indispensable to the power plant engineer. These decision support systems are intended to help control Operations and Maintenance costs.	http://www.ds-s.com/plant_monitoring_systems.asp
OSI PI Process Book	Available Now	OSI PI Process Book is an easy-to-use graphics package that allows users to create dynamic, interactive graphical displays.	http://osisoft.com/Products/Products%20A-Z/
Cognos 8 Business Intelligence	Available Now	This is a business intelligence (BI) product that delivers the complete range of BI capabilities: reporting, analysis, scorecarding, dashboards, business event management as well as data integration, on a single, proven architecture.	http://www.cognos.com/products/cognos8businessintelligence/index.html
Gartner Dataquest	Available Now	Gartner Dataquest offers a clear picture of more than 35 major IT and telecom markets with up-to-date statistics, forecasts, and analysis you can trust.	http://www.gartner.com/it/products_services.jsp
Centerview	Available Now	Applications that support data mining and dashboard presentations	http://www.corda.com/products/index.html
Obvient	Available Now	Applications that support data mining and dashboard presentations	http://www.obvient.com/
Celequest	Available Now	Applications that support data mining and dashboard presentations	http://www.celequest.com/
Qualitech Solutions	Available Now	Applications that support data mining and dashboard presentations	http://www.qualitechsolutions.com/
iExecutive Dashboard	Available Now	Applications that support data mining and dashboard presentations	http://www.iexecutivedashboard.com/
iDashboard	Available Now	Applications that support data mining and dashboard presentations	http://www.idashboards.com/
GridAgents	Available Now	Smart Monitoring and data filtering algorithms capable of adaptive decision making	http://www.infotility.com/; http://www.gridagents.com/ (dba as from Infotility)
Microgrid Control Software	Available now	Infotility's GridAgents Framework has built-in capability for Microgrid control.	http://www.infotility.com

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Grid Computing	Available Now	The Open Grid Forum (OGF) is a community of users, developers, and vendors leading the global standardization effort for grid computing. The OGF community consists of thousands of individuals in industry and research, representing over 400 organizations in more than 50 countries. Together they work to accelerate adoption of grid computing worldwide because they believe grids will lead to new discoveries, new opportunities, and better business practices.	http://www.ogf.org/About/ggf_abt_overview.php
Virtual Reality Telecommunication Systems (VRTS)	Tech Transfer from Telecom	Virtual Reality Telecommunication Systems (VRTS) will transmit human verbal and nonverbal communication messages; therefore, human to network interface considerations are essential. The VRTS will attempt to capture the entire human body by a set of sensors at the transmitting end and will convey these feelings to the human body at the receiving end with actuators.	http://www.wiley.com/WileyCDA/WileyTitle/productCd-0470848863.html
Self Organizing Maps	Available Now	Algorithms that use pattern recognition for presenting load profile and electrical network information.	http://www.grid7.net/; http://www.infotility.com; http://www.gridagents.com/ (dba as from Infotility)

Table 5: Improved Interfaces and Decision Support

SUMMARY

Key Technologies will fuel the development of the modern grid. Many of the required technologies are available today. Others are in various stages of development and are expected to contribute to grid modernization by the end of this decade. Undoubtedly, still others residing today in the minds of engineers and inventors will be revealed in the years ahead, particularly as the momentum for modernizing the nation's electric system grows.

This document has been prepared to provide interested parties an inventory of technologies for each of the five Key Technology Areas that are needed to support the Vision for the Modern Grid. It will be updated periodically. Users should consider the listed references as a starting point only since technologies will advance with time.

A collection of documents regarding related aspects of the Modern Grid have been prepared and are available for free download at the Modern Grid website. For additional information regarding the Modern Grid please use the resources listed below:

The NETL Modern Grid Initiative

Website: http://www.netl.doe.gov/smartgrid

Email: SmartGrid@NETL.DOE.GOV