Qualifications

System Automation, Protection, Control and Communication

Quanta Technology
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Executive Summary

Quanta Technology is a premier provider of planning and operations studies, technology evaluation, engineering standards and maintenance support, and expert advice to the electric power industry. Quanta Technology is an independent business unit of Quanta Services, the largest supplier of specialized engineering constructor services to electric power, gas and telecommunications industries in North America. (NYSE: PWR)

Quanta Services provides comprehensive infrastructure services for the electric, gas and telecommunications industries. This includes planning, design, construction, maintenance and operations for utilities, generators and large industrial users. Quanta Technology, headquartered in Raleigh, NC, has regional offices in Boston, MA and San Francisco, CA. Our mission is to help utilities and energy-critical industries achieve better performance through the application of technologies and technical best practices.

We offer a full range of technical and analytical capabilities including strategic and asset management planning, system planning and analysis, sustainable energy portfolio assessment, equipment design and maintenance standards, project and program implementation, operational excellence, consulting, regulatory support and training.

Our unique ability is to implement recommendations with minimal risk and resources. Our experts at Quanta Technology have considerable experience related to infrastructure operations, planning, engineering and construction, and the impact these have on an organization.

Commitment to Quality

Quanta Technology’s commitment to high quality, performance and customer satisfaction is supported and enforced through the authority of the highest levels of our company management. Our contract/project management approach is based on the following quality and performance process:

- Define customer requirements and objectives for business/technical, product or service.
- Measure and match performance to customer requirements.
- Analyze and assess process of business/technical strategy product or service implementation.
- Design and enforce array of steps required for successful implementation of product or service.
- Verify results and maintain high quality performance and customer satisfaction.
- Deliver product or service on time in a cost-effective way.

Service Offerings

Quanta Technology experts have guided major utilities as they evolve and update their designs and organizational support for transmission and distribution system/substation protection, control, communications. The multidisciplinary team works with clients to assess state of existing systems, and collaborates with the organization that deals with them. The strategic offering is structured for collaboration and organizational absorption of new designs and approaches, and aims at solving problems and bringing benefits that are uniquely relevant in each utility’s situation.
Statement of Expertise

Quanta Technology's expertise in the area of T&D system protection, control and communication solutions can greatly benefit utilities and their customers by improving reliability, adding flexibility, and increasing security of the grid and its equipment in a cost-effective manner. Specifically, the services we provide in the area of T&D system protection, control and communications include:

- Protective relaying methods and application in depth.
- Relay product and vendor offerings and evaluation.
- Communications systems and equipment for protection of transmission and distribution lines.
- Data communications for system/substation and enterprise integration including Ethernet networking.
- System/substation integration for SCADA, EMS, and enterprise users using communications, RTUs, host devices, concentrators, and substation servers.
- Communications protocols for system/substation integration including services of IEC 61850.
- Enterprise integration of information extracted from relay and intelligent electronic device (IED) data describing power apparatus measurements and events.
- NERC and regional reliability organization (RRO) standards – technical requirements and documentation for protection system maintenance, reliability and redundancy, disturbance monitoring equipment and methods, generator coordination, and other standards in effect or under development.
- Power system modeling and relay testing, including real time digital simulator (RTDS) testing.
- Wide-area protection coordination requirements, performance modeling, and software tools including Aspen OneLiner and CAPE.
- Power system and equipment studies and software – PSS/E and other tools.
- Synchrophasor technology and applications for wide area observation and recording, control, and protection.
- Distributed energy resource (DER) and renewable energy resources (RER) integration and impact on protection, automation and control.
- Industry practices benchmarking, condition assessment and on-site data collection.
- Conducting on-site seminars with multidisciplinary utility teams for instruction in basic principles and new technology, and for information gathering to support development of new programs, designs, and technical strategies.
- Development of technical roadmaps in light of the specific situation at the client utility, industry and technology trends, and management of risk in a multistep migration to new approaches.
- Implementation support – development of specifications, requests for proposals, and proposal assessment and vendor selection.
- Implementation support – owner’s engineer oversight of suppliers, installations, and testing.
- Development of documentation and test plans for operations, maintenance, and regulatory compliance.
Components for a System/Substation P&C Program

The Overview list, expanded below, is a toolkit from which Quanta Technology develops a client-specific strategy to address utility needs. Each client has specific circumstances, which Quanta first studies to develop the solution that is effective for that client.

A utility client typically seeks to assess its existing designs and systems and to develop new standards and roadmaps, or to determine how to achieve real benefits from highly promoted new technologies such as Smart Grid or IEC 61850 based substation integration. In other cases, the client has a specific problem or need requiring a targeted program engaging just a few skills from the list. Vendors enlist the assistance of Quanta experts for market study, product technical assessment, and technical specifications. Quanta offer a vendor-independent, unbiased approach for all of these needs.

Relaying Applications and Methods

Protective relaying of power systems is a complex and specialized art practiced by a limited number of experts worldwide. Effective protection design engages a variety of engineering disciplines. It requires overall understanding of the operation of each element of primary power apparatus, and the interactions of system components.

Quanta Technology brings a team of recognized industry experts, with decades of experience in relay application and design, to assess performance and develop new schemes. These experts are active in working groups or leadership roles in industry standards committees, including IEEE Power System Relaying Committee (PSRC), IEC Technical Committees 57 and 95, and NERC System Protection and Control Subcommittee (SPCS). They are noted authors and speakers on Smart Grid topics. These leading experts are supported by a team of technically experienced personnel to carry out larger investigations and projects. See sample resumes at the end of this document.

Relay Product and Vendor Offerings and Evaluation

Quanta experts have worked with manufacturers and utilities over decades in creation of leading advances in protection and control technology including:

- World’s first digital relays.
- World’s first communications-integrated substation protection and control system.
- Development of EPRI UCA substation integration communications architecture.
- Development of IEC 61850 international standard substation communications protocol.
- Development of pioneering phasor measurement systems – PMUs and client software.
These consultants work in the application of the latest generations of protective relays, integrated substation systems, and the newest design features. Quanta maintains an unbiased, independent stance with no vendor alliances, and works cooperatively with all equipment manufacturers. In project work, Quanta experts investigate and incorporate utility client relationships with vendors. Quanta projects help utility users map the relationship between product capabilities and features, and real needs for protection and control application today and in the future.

**Communications Systems and Equipment for Protection of Transmission Lines**

Protection communications for line relaying and transfer tripping is integral to protection. Quanta engineers are experienced in the detailed application of:

- Power line carrier communications equipment.
- Practices and design for carrier coupling systems including switchyard equipment.
- Multiplexed digital comm. systems – T1/E1 and/or SONET with microwave or fiber optic media.
- Direct fiber optic communications.
- Relay to channel equipment digital communications.

**Data Comms for System/Substation + Enterprise Integration incl. Ethernet Networking**

Modern substation integration systems connect communications ports of relays and substation IEDs to host devices and concentrators. Serial data comms are the most common today, but Ethernet networking is advancing rapidly as IT development yields simultaneous multi-protocol capabilities and cost effective integration options beyond what serial comms can achieve. Ethernet networking for substation applications require special expertise and attention that combines with but goes beyond what IT experts can bring. Substation P&C faces a hostile electrical environment, and supports mission critical and time critical messaging requiring hardware redundancy, monitoring, and substation-specific protocols.

**Substation Integration**

Communications of data with the right performance specifications supports operational needs – SCADA and EMS. Other data from the same substation relays and IEDs is required by the enterprise for event analysis, maintenance, engineering assessment, asset management, system planning, and other enterprise users. Modern integration architectures tie communications, RTUs, host processors or data concentrators, and substation servers to serve the needs of multiple clients at multiple remote sites. Quanta engineers are experienced in mapping data and information needs to unified substation integration architectures, including add-on systems and support of legacy systems.

**Communications Protocols for Substation Integration Including IEC 61850**

Quanta’s industry experts have participated in development of the IEC 61850 protocol since its inception in 1995, and through its absorption of EPRI UCA in 2000 to yield the single international multivendor standard for substation protection and data integration. IEC 61850 is a massive compendium of definitions of communications services and objects at several layers of the OSI 7-layer communication stack.
Utilities need help in relating these details to their applications and practical needs. They need to map specific services of IEC 61850 to design practical substation protection and control systems, with assessment of products, tools, risks, and risk mitigation strategies for each facet of the solution.

The most widely recognized IEC 61850 services on Ethernet are:

- **GOOSE Messaging** – publisher-subscriber service for transfer of status, control, and analog information among peer servers (interacting relays) at millisecond speeds equaling or exceeding the speed of dedicated point wiring that GOOSE aims to replace.

- **Information and Control Object Exchanges** - substation specific messages passed between servers (relays or IEDs) and clients (substation host computers or concentrators) for operational and non-operational data – local HMI, SCADA and EMS, and operations support.

- **Sampled Value or Process Bus Messaging** - for bringing switchyard power system data (such as voltage and current waveforms from VTs and CTs) from switchyard data collecting and apparatus control units (merging units) to relays in the control building on multiplexed Ethernet optical fibers that replace masses of switchyard wiring. This technology has triggered massive industry attention with the recent introduction of the first products from major vendors.

- **A Host of Other Services** – device configuration and parameter setting, file transfer for non-operational data, time synchronization, and more.

Automated configuration of networked devices from multiple vendors, based on IEC 61850-6 substation configuration language (SCL) is just emerging. As the industry absorbs these developments, the standards writing teams continue with new features and services including objects for new applications (hydro power plants, distributed energy resources) and new communications applications reaching outside the substation to control centers and to other substations for teleprotection applications.

Each of these services and applications has specific purposes, risks and benefits, and the risks evolve as vendors continue product development. A Quanta Technology IEC 61850 strategy project maps these factors to the needs and circumstances of the utility, weighing alternatives and risks in the process.

As a starting point for utilities seeking to engage with IEC 61850, A Quanta Technology conducts seminars to explain the features, services, applications, risks, and industry experience. This lays the groundwork for development of a plan for field trial or practical utilization. This approach applies for the complete IEC 61850 protocol services suite, or for particular services of interest like sampled values/process bus for multiplexed optical switchyard to control house communications.

**Enterprise Integration of Information**

Data extracted from relays and intelligent electronic devices (IEDs) describes power apparatus measurements and events, and the masses of available data can overwhelm the user. Integration strategy looks at how to gather, process, and convert the data to information that serves users across the enterprise.
NERC and Regional Reliability Organization (RRO) Standards

NERC, with backing and pushing by FERC, is writing and enforcing technical requirements and documentation for protection system maintenance, reliability and redundancy, disturbance monitoring equipment and methods, generator coordination, and there are other standards in effect or under development just in the protective relaying domain (PRC standards series). There are hundreds of additional standards for other aspects of utility operations and planning. Quanta experts participate in NERC standards development, and bring first-person knowledge of standards under development that can impact the suitability of designs and plans for compliance and documentation.

Power System Modeling and RTDS Relay Testing

The most challenging EHV line protection applications require testing of relays in that particular situation, to demonstrate performance and determine settings. Modern computer simulation based relay testing includes development and validation of transient models of the power system application, and transfer of the model to a real time digital simulator (RTDS) laboratory closed-loop test system. For less demanding tests, the computer power system modeling tool generates a COMTRADE transient event file for open-loop playback in relay test sets. Quanta conducts these tests to select and set relays for critical applications.

Protection Coordination

Coordination studies can logically be included with overall protection strategy study, but are generally conducted as separate evaluation projects. Activities include data mining and collection, power system model creation and/or validation from transmission line, apparatus, and topological data; protective relay terminal behavior model configuration, fault studies, and coordination checks, and resolution of miscoordination problems. The Quanta team of experts conducts studies using Aspen OneLiner, CAPE, and projects in which study data is ported between the two programs to take advantage of existing data bases and particular computational features. Quanta have experience with studies of HV and EHV protection for an entire multi-state region.

Synchrophasor Technology and Applications

Synchrophasor measurements and phasor measurement units based on IEEE C37.118 promise precise wide area power system state observation, disturbance recording, and wide area control or protection. Synchrophasor applications have drawn the attention of the industry for several years, and the latest generation of protective relays includes this measurement capability. Quanta consultants, managers, and associates include some of the industry’s most recognized experts in phasor measurements, including inventors of the concept and leaders of standard development. Quanta is a major participant in and contractor developing industry-wide networking for the North American Synchrophasor Initiative (NASPI; formerly EIPP) under sponsorship of the Department of Energy. Quanta assists utilities with practical applications of synchrophasor technology.
**Distributed Energy Resource (DER) and Renewable Energy Resources (RER) Integration**

Quanta engineers have solved problems of DER and RER integration, and are working on leading edge projects for future DER and RER integration as part of the Smart Grid. DER and RER integration includes protection issues and impact on distribution and transmission systems, communications with distributed resources, and unified automation and control of these resources in coordination with operation of the formerly centralized grid.

**Industry Practices Benchmarking**

Quanta engineers have long standing relationships with protection and control engineers across North America and the world, and decades of participation in industry standards committees and forums. This accumulated experience provides a base for comparison of all aspects of protection and control with the range of industry practices. Beyond this, Quanta has conducted surveys on targeted benchmarking topics to gather data to support detailed or critical evaluations and design decisions.

**Condition Assessment and On-site Data Collection**

A critical component in the early phase of a strategy and technical roadmap development is a hands-on survey of typical substations, including interviews with field personnel responsible for protection and control systems there. This identifies the existing problems to solve when developing new plans. It also defines the nature of the organization in which new standard design solutions must be absorbed if the new designs are to perform successfully and improve operations.

Also, a more widespread assessment of a fleet of equipment across the system to determine or justify replacement need as part of a capital program, or to develop priorities for replacement when capital or manpower limit the rate of progress.

**Conducting On-site Seminars**

Quanta conducts seminars and training sessions with multidisciplinary utility teams for instruction in basic principles and new technology, and for information gathering to support development of new programs, designs, and technical strategies. This engagement and exchange is a critical element in an overall program for introduction of any new technology, or development of new standards. The discussion gives the utility teams a basis for focused planning, and for integration of activities that must coordinate for successful introduction of new designs. Stakeholders who may participate include protection engineering, communications engineering and/or information technology experts, protection and communications maintenance engineers and technicians, control center and operations experts, asset managers, system planners, and system performance analysis teams.
**Development of Technical Roadmaps**

Before planning specific new designs or standards, Quanta works with clients to develop a long range roadmap that considers the organization’s practices and philosophies, future objectives, experiences and problems, and industry trends. In this way, the utility can manage risk as it moves gradually towards its future goals, and can avoid orthogonal steps that delay future benefits for another equipment generation.

**Implementation Support**

Once the technical plans and high level specifications are adopted, utilities may need help with implementation. Quanta brings experience in dealing with vendors and new products, as well as manpower to reduce the workload of a fully burdened utility team while maintaining collaboration and utility awareness. Implementation activities by Quanta engineers include development of detailed specifications and requests for proposals. Quanta supports or leads a process of objective proposal assessment and vendor selection. Quanta personnel can serve as owner's engineers who oversee suppliers and installations. The Quanta team has experience with development or review of test plans and results for new equipment and system designs for substation protection and control.

**Development of Documentation**

Quanta team members with utility experience can develop operating, maintenance, and test plans including documentation for regulatory compliance.
Key Personnel

The Quanta Technology T&D system protection, control and communication team consists of world-class experts in the area of substation and feeder automation, protection and control, communication systems, power system operation and engineering, system enterprise integration and other disciplines that are key to the success of your project. Brief biographies of key team members are provided below. Quanta Technology also has additional team members and resources available to support projects as needed.

Bryan Gwyn, Ph.D.

Bryan has over 30 years’ experience in the Utility Industry with over 20 years’ experience in Protection and Control. Bryan was Director of Protection, Telecommunications and Metering at National Grid prior to joining Quanta Technology in 2011. He was responsible for delivery of multi-million dollar Capital Projects, Standards development, system disturbance analysis, NERC Standard compliance and Asset Strategy in these fields of engineering. He has held several leadership positions including managing teams in Protection Engineering, Standards and Events Analysis. He moved to the U.S. in 2001 from National Grid in the U.K. where he held several senior positions in Protection and Control Engineering. Bryan is a Senior Member of the IEEE and has co-Chaired several Working Groups at the Power System Relay Committee. He is Chair of the Boston IEEE PES Chapter that recently won the most Outstanding Chapter award. He is also a Member of the Institute of Engineering and Technology and a Chartered Engineer in the U.K. He is a Member of the NERC System Protection & Control Subcommittee and is a past Chair and Lifetime Member of the NPCC Task Force on System Protection. He is a Member of a CEGRE Working Group on Managing Relay Settings and has published over 20 papers and articles. Bryan holds a Bachelor degree in Electrical and Electronic Engineering and a PhD from the City University, London.

Juergen H. Holbach, Ph.D.

Juergen Holbach has more than 20 years of experience in design and application of protective relaying. He led the development project for the second generation of numerical line differential relays for a German relay manufacturer. As an application expert for transmission protection he was responsible for approval test of transmission relays with utility customer around the world. Since 2000 he works in the U.S. as a product manager for protection relays. Juergen was one of the lead engineers on the first IEC61850 based Protection and Control, Multi-Vendor Project in the United States (500KV Bradley Station-TVA).

Juergen contributed to several working groups in CIGRE as well as in IEEE-PSRC and is the chairman of the working group HS “Common format for IED configuration data”. He is also member of the IEEE-PSRC subcommittees “Relay Practices” and “Relay communication”. He published over a dozen papers at the major relay conferences in North America. Juergen holds several patents in the area of protection relaying.

Prior to joining Quanta Technology, he was Product Lifecycle Manager at Siemens Energy Inc. in Wendell North Carolina. He was born in Germany and graduated from the University of Berlin with a PhD in Electrical Engineering. He joined Siemens AG in 1992 as a development engineer in Berlin Germany. In 1994 he moved to the product management group for protection relays in Nuremberg Germany. In 2000 he joined Siemens Power and Distribution in Wendell, NC as a product manager for transmission relays.
Eric A. Udren, MSEE

Eric A. Udren is an Executive Advisor with Quanta Technology. Mr. Udren has a 39 year distinguished career in design and application of protective relaying, control, and communications systems. He is a Fellow of the IEEE, Member of the IEEE Power System Relaying Committee (PSRC), Chairman of two PSRC Standards Working Groups, and Vice Chair of the Relaying Communications Subcommittee. On two occasions, in 2001 and 2006, he received the PSRC Distinguished Service Award. He serves as Technical Advisor to the US National Committee of the IEC for TC 95, Measuring Relays. He also serves as a US Delegate to IEC TC 57 Working Group 10 responsible for development of IEC 61850 standard substation communications protocol. Eric serves as a member of the NERC System Protection and Control Subcommittee (SPCS, former SPCTF), and the NERC Protection System Maintenance Standard Drafting Team. He has written and presented over 80 technical papers and chapters of books on relaying topics, and has taught courses on protection, control, communications, and integration. He holds 8 patents on relaying and power-system communications. He received his BSEE from Michigan State University in 1969, MSEE degree from New Jersey Institute of Technology in 1981, and the Certificate of Post-Graduate Study from Cambridge University (UK) in 1978. He has worked at Westinghouse, ABB, Eaton Electrical (Cutler-Hammer), KEMA, and Quanta Technology.

Solveig Ward, MS

With over 34 years' experience working in a variety of managerial, product management and marketing roles in the protective relaying and relaying communications area, Solveig brings a wealth of knowledge and ability to her role as Principal Advisor for Quanta Technology, Protection and Automation group. Combining relay expertise with communications knowledge, she provides leadership in the area of communications systems for power system protection and control including IEC 61850, cyber security and integration issues.

Solveig is an application expert in current differential and pilot relaying. During her time with ABB, she was a product manager for line differential relays (pilot wire, phase comparison and current differential) and was involved in developing a new current differential relay. At RFL, she continued in this line of business, being project manager for a new current differential relay and communications product. She has written and presented many papers in relation to pilot relaying, current differential relaying, and associated communications, both digital and analog. She has also written application guides for settings of current differential relaying and wrote and presented a paper on this topic, as well as application guides for settings and coordination of pilot distance protection.

Solveig is a Senior member of IEEE and Chairman of its System Protection Subcommittee. The scope of the System Protection Subcommittee is to “Evaluate protection system responses to abnormal power system states. Evaluate and report on special protection schemes, remedial actions schemes, monitoring and control systems and their performance during abnormal power system conditions. Recommend corrective strategies and develop appropriate standards, guides, or special publications. Evaluate and report on new technologies which may have a bearing on protection system performance during abnormal power system conditions.” Working Groups in this subcommittee deal with wide area protection and there are several synchrophasor IEEE standards presently under development.

Solveig is very active in Working Groups and initiated and chaired groups producing reports for Cyber Security and for Redundancy. She is presently serving as a Vice Chair for a Working Group developing an IEEE Guide for Current Differential Relaying.
Solveig received an IEEE award in 2011 for PES Working Group Recognition Award - Outstanding Technical Report for “Redundancy Considerations for Protective Relaying.” She also received an IEEE PES Prize Paper Award in 2011 as a co-author of “Performance of Relaying during Wide-Area Stressed Conditions.” Solveig’s interest and involvement in Cyber Security go back to 2004 when the CIP Urgent Standard was first issued, and she has kept abreast of developments in the Cyber Security area since then. She attended NERC workshops and discussed with utilities in order to understand Cyber Security requirements to take into account for new substation relaying and communications product development.

She initiated and chaired a PSRC working group, resulting in a technical report “Cyber Security Considerations for Protective Relaying” in 2007. She is presently an active member of PSRC WG H13 that will produce a Cyber Security guide for protective relaying. Solveig has authored over 25 papers presented at domestic and international relay and communications conferences. Several of them have also been published as magazine articles. She is co-author of three transaction papers, co-editor of one book, and holds one patent in the relay protection field.

Farid Katiraei, Ph.D.

Dr. Farid Katiraei is a Technical Advisor with Quanta Technology. Dr. Katiraei is a power engineering expert in the area of decentralized energy system design and integration of renewable energy sources. He received his B.Sc. and M.Sc. degrees in electrical engineering from Isfahan University of technology (Iran) and his Ph.D. degree also in electrical engineering from University of Toronto (Toronto, Canada). Farid has several years of professional experience with design, modeling and implementation of power electronic apparatus for power system applications as either interface medium for emerging generation sources or active power conditioners. He has been involved in control and protection system design, connection impact assessments and project commissioning of several privately owned distributed generation projects with various technologies including Solar PV, wind turbine and hydro power generation as well as diesel and/or biogas engines. He has organized and spoken in many technical conferences and symposiums. He is an active member of IEEE, a steering committee member of international collaboration on Microgrids, and an active participant in several international standard development working groups as part of IEA and IEC taskforces. His main expertise includes applications of power electronics in power systems, grid interconnection and utility impact assessment of distributed renewable energy sources, distribution system automation, and study of emerging architectures for distribution system planning and design based on Mini-Grids, Microgrids, and Smart-Grids approaches.

Yi Hu, Ph.D.

Dr. Yi Hu, Director of WAMPAC for Quanta Technology, is one of the nation’s leading technology and business development experts in electrical power system analysis, operation, protection, and control. During his 23 years in the electrical power industry supporting utilities and vendors, he has developed concepts and methods to improve power system operation, protection and control and was awarded 13 US and multiple international patents. His work has earned him the industrial recognition in the field and he currently is an IEEE Senior Member. Dr. Hu has published a number of articles and technical papers in Refereed Journals and Conference Proceedings in the areas of power system analysis, protection, control and prevention of power system outages through the application of wide-area monitoring, protection and control technologies.
Vasudev Gharpure, Ph.D.

Dr. Vasudev Gharpure has more than 27 years of industrial and academic experience in three countries. He has designed the hardware and firmware for digital and analog protection relays, a phasor measurement unit, a power system stabilizer and other real time embedded systems based industrial products. His areas of interest and expertise are in protection and control of power systems, power electronic based utility applications such as static VAR and other FACTS based systems, embedded control applications, motor controls, numerical algorithms, automation and automated test equipment. Prior to joining Quanta Technology, he was Consulting Design Engineer at ABB Inc. in Raleigh / Cary, North Carolina for ten years. Prior to that, he was Principal Design Engineer at Basler Electric in Highland Illinois. He has also held positions at Virginia Tech, Virginia; Singapore Polytechnic, Singapore; Eastern Peripherals, Mumbai, India and Tata Electric Companies, Mumbai India. He is a member of IEEE and a member of the C37.118 Synchrophasor standard working group of the IEEE. He has authored several publications in the course of his career.

Trevor Hall

Mr. Trevor Hall has worked for thirty seven years in various technical and leadership roles. Trevor Hall was a Senior Telecommunication Technical Specialist with Pacific Gas and Electric Company for twenty five years in the fields of microwave, computer and power line carrier systems supporting electric transmission relay protection. His responsibilities included new equipment evaluation, maintenance planning, class instruction of maintenance personnel and start up coordination. Trevor Hall was also a maintenance supervisor and technician for the remainder of his thirty seven year career. Mr. Hall was a member of a Remedial Action Scheme first response team at Pacific Gas and Electric Company, requiring vast knowledge of electrical grid interconnection and telecommunications infrastructure. Mr. Hall was a member of PG&E standards team for protection and control, and has also participated in company provided trainings such as the applications of IEC-61850. Mr. Hall was member of Modular Protection Automation and Control (MPAC) development team. Trevor Hall also served in the U.S. Navy and Coast Guard reserve and reached the rate of Senior Chief Electricians Mate. Most of his active duty time was working on shipboard steam, T&D Automation Confidential/Proprietary Page 9 of 12 diesel, gas turbine propulsion control and electric generating systems. Trevor Hall has attended thirty one factory training classes, holds a diploma in Electronics Technology, and has a FCC General Radiotelephone Operators License.

Ali Mirhadi

Ali Mirhadi, Principal Advisor, has a vast experience in the field of power system study and transmission & distribution protection system. His wide-ranging experience spans across both industries and utilities in North America. His areas of expertise are in power system modeling and analysis, protection and control system design, renewable energy systems, and arc flash studies.

Majida Malki, PE, PMP

Majida Malki, Advisor, has more than 17 years of experience in design and applications of Protective Relaying and Control for the power utility industry. Her areas of expertise are protective relay settings and coordination, protection, control and substation automation, power system modeling and analysis, and T&D loss studies, power quality, and project management.
Reference Projects

The following is a selected list of relevant projects and industry activities that members of the Quanta team have participated in recent years. Brief project descriptions are provided below and detailed descriptions are available upon request.

Wide Area Protection Coordination Studies, System Protection, Special Protection Scheme and DER Protection

1. National Grid - Wide-Area Protection Simulator Development and Coordination Study:

Quanta Technology (prime contractor) and Electron International have been engaged to develop a wide-area system protection simulator tool and perform a dynamic wide-area protection study for the National Grid 115kV-345kV transmission systems in New England and New York. The project goal is to determine appropriate protection settings to assure secure wide-area protection coordination and system reliability in the event of local and wide-area faults.

Our project scope includes:

- Gathering data, validating and developing a database from National Grid, 12 neighboring utilities and ISO databases for computer modeling. The database will be used to develop the protection coordination modeling system, perform project studies and be retained for future reuse by National Grid. The database will include:
  - Primary power system of National Grid transmission line and substation equipment design and operation characteristics
  - Protection system (secondary system) device types, connections, operational characteristics and settings for the entire National Grid area, which includes traditional electro-mechanical relays and contemporary “smart” relays
  - Similar data from neighboring utilities and ISOs of interconnection equipment
  - Validation of the updated power system (primary) model data through comparative results and benchmarking against actual recent fault recordings
  - Primary system database in new (CAPE) and legacy system (Aspen OneLiner) formats
  - Design, use and deliver a computer-based modeling tool that generates relay settings and data bases using parameters for approximately 650 line terminals, associated transformers and generators within National Grid’s territory. The system will enable dynamic simulation of short-circuit faults at thousands of locations in the National Grid system and neighboring utility systems to assess protection system responses and develop appropriate settings.

2. Allegheny Energy Services Corporation - Relay Setting Macros Development:

Project included the relay setting macros development. The standard CAPE Relay Setting module computes relay settings for a two-terminal or three-terminal line with a directional comparison blocking (DCB) pilot scheme. This scheme uses phase and ground distance relays and backup ground overcurrent relays. Allegheny Power Company provided a summary of setting rules. Electrocon had previously implemented macro code for network searching and reach calculations, with user-chosen ratios of desired reach to line impedance.
Electrocon provided the following CAPE Relay Setting algorithms using rules supplied by Allegheny Power:

- Phase MHO distance elements at two or three line terminals with or without breaker failure schemes, including loadability limits. Fixed timer settings. All settings applied to generic or SEL relays.
- Phase distance reverse distance zone 3 coordinated with facing zone 2, on two-terminal or three-terminal lines.
- Pickup settings for backup directional ground overcurrent relays, using fault studies with outages.
- Coordinated TOC time-dial settings based on OGE algorithms.

3. **Entergy - Development of entire protection settings and schemes for 500kV Bottom Holland substation:**

Quanta Technology was selected to develop the protection settings for all relays of a new 500kV/168kV/115kV Bottom Holland substation in the Entergy system. The Bottom Holland substation consists of 6 lines, 2 autotransformers and 2 buses. The project included the protection system parameter calculations and modeling of the entire substation and associated elements using ASPEN OneLiner Database. Fault current studies and coordination studies were also performed in ASPEN. In total relay setting and schemes were developed for 39 numerical relays. Project deliverables included: electronic setting files in vendor format for all relays, setting calculation documentation and revised protection system model and database.

4. **Lone Star (FP&L & NextEra) - Design, engineering and implementation of protective relaying setting and schemes for three new 345kV substations and associated transmission lines with series compensated lines:**

Lone Star is building 2 new series compensated 345kV transmission lines, connecting 3 new substations. Quanta Technology was selected to develop all relay settings for this complex application and review and revise existing relay settings on adjacent lines. The series compensated lines are partially in parallel and have two series capacitors on each line. The project included the modeling of all new elements and adding them in the existing Aspen Database. Aspen was used for all fault current studies and coordination studies. In total there were 140 electronic relay files for numerical relays, including calculation documentation delivered to the customer.

5. **Pacific Gas and Electric - Out-of-Step System Studies, Scheme Review and Recommendations:**

Project included wide area system studies, development and implementation of “Out-of-Step” protection alternatives for 500kV and 354kV transmission system as recommended by PG&E’s Planning Department. Quanta Technology provided system studies/analysis and evaluation of protection devices/schemes available in the industry in order to recommend suitable Out-of-Step (OOS) blocking and tripping schemes for all 230 kV and 500 kV transmission lines. Additionally, the project team reviewed PG&E’s existing protection device in order to identify their blocking and tripping usability. A proposal for new devices to ensure Out-of-Step functionality in the designated power sub-system and OOS coordination and selectivity with existing RAS (SPS) was also
performed. New devices were evaluated for future capability to implement Phasor Measurement Unit (PMU) or synchrophasor technology and to interface with PMU data concentrators.


Designed architecture and developed strategies for deployment of fully integrated RAS schemes for 110kV, 230kV, 345kV and 500kV transmission systems. Based on system specification, products to fulfill stringent system requirements were selected. Deployed HW/SW to support latest technology developments (such as IEC 61850 protocol) enabling future-proof solutions and positioning the system for functionality and reliability upgrades.

7. Natural Resources Canada - Commercial Anti-Islanding Protection Study:

The objective of this project is to survey commercial products that have been used to implement “anti-islanding protection” for Distributed Generation and prepare a summary table based on category of application (DG type, and size) and product specifications (price, characteristics, previous usage, etc.). The investigation will consider a national scope for application in USA and Canada. As a secondary objective, the table summary will be used to identify type and essential features of multifunctional generator and/or inter-tie relays in the market that can be recommended for passive schemes.

8. Natural Resources Canada - Biogas DG Dynamic Protection Islanding Studies:

The objective of this project is to analyze transient behavior of a 500 kW biogas generator upon disconnection from the grid and islanding in order to select proper passive anti-islanding protection schemes for the DG inter-tie protection. The study system consists of a farm-based biogas DG which is connected to a rural feeder with minimum load equal to the DG size. As part of the study, a transient model of the system including the feeder, DG, load and distribution transformer station is built in the PSCAD/EMTDC environment and being used to investigate performance of several protection schemes. The focus of study is on performance evaluation of voltage and frequency based protection schemes such as negative/zero sequence voltage, Vector Shift and rate-of-change-of-frequency (ROCOF). The study covers investigation of several realistic scenarios and system operating conditions under balance/unbalance load and generation along with analysis of sudden load variations to determine sensitivity of schemes and optimal range of settings. The outcome of the study is used to propose reliable protection schemes for the purpose of DG interconnection to the grid.

9. Southern California Edison, Short Circuit and Protection Coordination Studies:

This project assessed the impact of several new generation units (from 50 to 700 MW) on the Southern California Edison protection system. Quanta Technology performed protection coordination study at the 66 and 115 kV busses/lines for more than thirty 220 kV substations to evaluate possible protective relay misoperation due to added generation units. Based on the finding new/revised protection settings were recommended.
Technology Assessment and Standards Development

1. Pacific Gas & Electric Company - 500 kV Protective Relaying Redesign:

Quanta consultants began with a seminar among the Quanta team members and many departments of PG&E including protection, automation, communications, IT, operations, maintenance, and planning. Quanta assessed the diverse generations of equipment installed in the field, and evaluated features of new relays for testing. Quanta carried out a major industry benchmarking survey of 20 major utilities on EHV protection and control practices and experience. A Quanta team ran a comprehensive RTDS relay testing program for PG&E, which included selection and contracting of a test lab, creation of a test plan, implementation of a system model for a group of series compensated lines with nearby facilities, cooperative test arrangements with four relay vendors for six products, development of settings, and performance and documentation of the tests. Final products were selected based on performance, strategy roadmap developed by Quanta with PG&E, and benchmark results. Quanta provided specific design requirements for new protective relaying systems, protection communications, and substation networking and integration functions. Quanta interactively developed a business case, and supported the PG&E project team in management presentations and project result presentation to the organization. The work continues with detailed standard design development and deployment across the PG&E 500 kV system, in cooperation with a panel building and engineering firm contracted by PG&E.

2. PacifiCorp Energy - Development of Protective Relaying Standards:

Project provided a complex support to customer’s Engineering Department with a protective relaying standards development (generation, motor and transformer) and support with protective relay schemes review and recommendations. In addition protective relay products evaluation and selection support was provided.

Substation Automation

1. Pacific Gas & Electric Company IEC 61850 Process Bus Assessment:

Despite the dramatic changes in technology within substation control buildings, very little has changed in the substation yard. The connections between the new IEDs in the control building and the equipment in the sub-station yard (instrument transformers, circuit breaker trip coils, equipment alarms, etc.) are still handled in an analog fashion using copper wiring. The IEC 61850-9-2 standard defines a digital approach for handling the connections between IEDs and substation yard equipment. This study include an assessment of using IEC 61850 process bus technology at both transmission and distribution substations. The specific objectives of this study are to:

- Determine the feasibility of using the GE “brick” optical fiber equipment with protective relays from GE and other relay manufacturers (such as Schweitzer) and with the existing Monitoring, Protection, and Control (MPAC) systems.
- Review the benefits and costs identified to determine the economic justification for using the technology.
- Identify the shortcomings and potential barriers to successful deployment.
2. **Industry Survey of SA Products:**

   Given the recent surge of interest and demand within the electric utility industry for new technology equipment to support evolving long term and short term “Smart Grid” strategies, there has been sharp competition among vendors to satisfy this demand. Quanta Technology recently conducted a comprehensive survey to identify electric utility SA/DA needs and competing Vendor products to address these needs. The project also included a broad-based, independent and unbiased assessment of competitors, market trends, market application requirements assessing the general market pricing.

3. **Duke Energy Distribution Substation Automation:**

   Prepared procurement documents and assisted during all implementation phases for distribution substation automation project. System included interfaces to various substation Intelligent Electronic Devices (IEDs) including protective relays, transformer management devices, and programmable controllers via wired and wireless media. System was interfaced to Duke IVVC system as well as corporate data warehouse (OSISoft “PI”) for accessing “non-operational” data.

4. **National Grid - System of the Future:**

   Project included development of blueprint for addressing the needs and requirements of the protection, automation and communication infrastructure in the National Grid service area over the next 20 years. While there are many exciting concepts and technologies being proposed in the utility industry, the objective of this project is to present a practical discussion of where the system will go and how the customer should get there. The future needs of customers; the impact of an aging infrastructure, the evolution of an ever-changing variety of product choices, and cost considerations are being evaluated. Standardization of practices in the various service areas covered by National Grid and the impact on system performance is also being examined.

**Distribution Management Systems**

1. **BC Hydro Distribution Management System:**

   Quanta Technology is currently assisting BC Hydro and BC Transmission Corporation with the procurement and implementation of their new Distribution Management System (DMS). This system is a decision support tool that will enable distribution system operators and other BC Hydro personnel to continuously monitor all BC Hydro distribution assets, including substation facilities, overhead and underground feeder (“field”) devices, network facilities (including spot networks and underground secondary networks, and distributed generating facilities via SCADA facilities and interfaces to external systems. The system includes special applications, such as volt-VAR optimization and predictive fault location, which will enable BC Hydro to improve power system efficiency and reliability. Quanta Technology is serving as the DMS “Subject Matter Expert” for BC Hydro, and has played a lead role in requirements definition, development of technical specifications, and vendor selection.
Distribution Feeder Automation Implementation

1. **ENMAX Power Corporation DA Project:**
   
   Performed needs analysis including detailed distribution feeder modeling, DA system conceptual design, benefit cost analysis, and implementation planning that laid the foundation for this feeder automation project, which was awarded “Automation Project of the Year” at Year 2004 DistribuTECH conference. Also, developed procurement specifications and assisted in vendor selection for this project.

2. **Duke Energy Integrated Volt-VAR Control (IVVC) Project:**
   
   Prepared procurement documents (including detailed technical specifications) for advanced DA system to optimize operation of distribution capacitor banks, substation load tap changer transformers, and feeder voltage regulators. Assisted in vendor selection and performed project implementation activities through final system commissioning.

Wide Area Monitoring

1. **Department of Energy (DOE)/National Energy Technology Laboratory (NETL) NASPInet Design and Specifications:**
   
   The overall objective of this project is to create a robust, widely available and secure synchronized data (Synchrophasor) measurement infrastructure for the interconnected North American electric power system with associated analysis and monitoring tools for better planning and operation, and with improved reliability. Quanta Technology’s role in this project is to develop and deliver specifications of NASPInet, based on the above high level conceptual design of NASPInet and its associated requirements detailed in the RFP, to DOE NETL. NETL is expected to use these specifications in the subsequent procurement and implementation of the NASPInet.

Planning and Assessment Studies

1. **ENMAX Power Corporation:**
   
   Assessment of Existing DA System Performance: Performed a detailed assessment of DA system performance over a three year period of actual system operation, estimated the reliability improvement that is attributable to DA, reviewed future DA implementation plans and made recommendations pertaining to this plan.

2. **National Grid U.S. – System of the Future:**
   
   This is an ongoing project to investigate and present a general pragmatic blueprint for addressing the needs and requirements of the protection, automation and communication infrastructure in the National Grid service area over the next 20 years. While there are many exciting concepts and technologies being proposed in the utility industry, the objective of this project is to present a practical discussion of where the system will go and how the customer should get there. The future needs of customers; the impact of an aging infrastructure, the evolution of an ever-changing variety of product choices, and cost considerations are being evaluated. Standardization of practices in the various service areas covered by National Grid and the impact on system performance is also being examined.
3. **Manitoba Hydro - Vision for Distribution Operation and Automation:**

Performed a comprehensive study to determine the best long range strategy for the operation and automation of Manitoba Hydro’s distribution system, which was decentralized (operated without a control center) and had no remote monitoring and control facilities. Strategy recommended was creation of three regional operating centers and a gradual transition from decentralized to centralized operation in urban and suburban areas of the Province. In addition, the study recommended ways to access information from existing substation IEDs for engineering and maintenance purposes.

4. **Michigan Electric Transmission Company (METC) - Protection and Automation Study:**

Performed a detailed study to identify ways in which METC could gain access to the wealth of operational and non-operational data contained within protective relay IEDs installed at METC’s transmission substations. The study identified new applications made possible by having access to this data, a standards based conceptual architecture for substation automation and integration architecture, and a detailed strategy for implementing this architecture without disrupting ongoing operations. The study also included a detailed benefit cost analysis to determine the economic justification for performing the recommended changes.

5. **Exelon Generation Company:**

Developed emergency response contingency plans.

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**Knowledge Transfer**

1. **Distribution Automation – Strategies for Success:**

   Full day “Utility University” seminar presented at DistribuTECH 2008. Topics covered include automated switching, Volt VAR control, DA equipment, DA systems architecture and available offerings, communication facilities, role of DA in the “modern grid”, developing the business case for DA, and implementation strategies for success. Similar full day seminar conducted at the National Rural Electric Cooperative Association’s (NRECA’s) TechAdvantage Conference in 2007. Tailored seminars covering the same topics were presented at Manitoba Hydro, ENMAX Power Corporation (Calgary), EPCOR utilities (Edmonton), and others.

2. **Substation Automation:**

   Full day “Utility University” seminar conducted at DistribuTECH through Year 2006. Topics covered include high value SA functions, SA equipment and systems architecture, enterprise access to substation data, standards and protocols, vendor offerings, developing the business case for SA, and implementation strategies. Tailored SA seminars also have been conducted at individual utilities such as Dominion Resources.

3. **Down Line Automation – A Guidebook for Electric Distribution Coops:**

   Prepared a distribution automation guidebook for electric distribution coops under funding from the NRECA’s Cooperative Research Network. Topics covered include DA applications, systems and equipment, making the right choices (the business case), communication systems, and implementation strategies.
4. Distributed Generation – Protection, Automation and Control:
   Two-day seminar presented for various North American Utilities (e.g. Pacific Gas & Electric, BC Hydro, etc.)

5. Substation LANs and IEC 61850:
   Seminars conducted at National Grid US, British Columbia Hydro, and Israel Electric Corporation in 2008. Topics include history and principles of 61850, explanation of services, GOOSE messaging focus, process bus applications, industry certification program, product assessments, and requirements for underlying Ethernet networks.

6. Substation Protection, Control & Communications in the New Century:
   Full-day Utility University course taught at DistribuTECH each year from 2006 to 2009, with updated content at each session. Microprocessor-based protective relays and substation IEDs are the eyes and ears for modern integrated substations. They protect the power system, control and monitor apparatus and connect via LAN and WAN to exchange data with substation host computers and the utility enterprise. This course examines sea changes in application of protective relaying and substation control systems in light of new product designs, industry trends and the changing regulatory environment. It explains technologies for enterprise-wide communications to support business integration. This seminar covered the following topics:
   - Trends in design and application of protection and control for lines, buses, transformers, and circuit breakers
   - Benefits and challenges for LAN-based protection and control
   - System-wide communications for protection, control, and data gathering
   - Wide area power system measurements for monitoring and protection
   - Planning & optimizing communications networks to support system traffic
   - Communications transport architectures to ensure performance and reliability
   - New protection and control panel design, user interfaces and maintenance approaches

Standards Development
1. IEC Technical Committee 57 Working Group 10:
   Participation since 1995 in development of the complete IEC 61850 Edition 1 standard now in effect (sections adopted at various times since 2003). Continued membership as WG 10 develops Edition 2 and new sections.

2. Participation since 1995 in WG 12:
   Responsible for process bus parts 9-1 and 9-2 of 61850, now absorbed in WG 10.

3. Support and contributions towards development of a harmonized communication systems standard for Distributed Energy Resources (IEC 61850 Part 7-420 DER Logical Nodes):
   Quanta consultants have contributed to development of a new part of IEC 61850 that introduces data attributes and communication system structure for DER technologies. The work is organized under TC57 WG17 and expands the definition of logical devices and logical nodes required to
model various DER. The First Draft International Standard (FDIS) for “IEC 61850 Part 7-420 DER Logical Node” is prepared that introduces the object models and services for information exchange requirements for distributed energy resources (DER), comprising dispersed generation (DG) devices and dispersed storage (DS) devices, including reciprocating engines, fuel cells, micro turbines, wind turbines, photovoltaic, and storage devices.

4. **Participation in UCA International Users’ Group Testing Subcommittee:**
   Responsible for implementation of the industry conformance assessment lab and product certification programs and testing specifications that are compliant with IEC 61850-10.

5. **NERC generator protection standards:**
   Responsible for development of the NERC Standard. Provide analysis of generator controls and protection performance and improvement recommendations to support event analysis and information exchange at NERC.

6. **PacifiCorp Standards:**
   Developing standards for generator controls and protection.

7. **Calpine’s Power Plant Disturbance Analysis:**
   Support with event and root cause analysis.

8. **Brownville Papers:**
   Support with repair and upgrade of the generator electrical system.