1. SUMMARY

This paper seeks to present the path that Saudi Electricity Company (SEC) has undertaken to implement the IEC 61850-based substation automation amidst problems in the standard and reluctance of a number of operators, in addition to IEC 61850 brief backgrounders. Presented is a pilot project of SAS-based substation that is in the drawing board.

Presented are the major lessons learned and consolidated to be applied in succeeding projects, and in extending the SAS beyond one station to adjacent ones, as well as migration to SAS in other substations. Also anticipated in the industry is the IEC 61850 extension to the Control Center from the substation, inter-control-center application of the SAS technology, as well as extension of the SAS to the process bus. The lessons consolidated will be used to face these upcoming challenges. The paper also describes the formation and functioning of the EPRI calls the technology group, which in SEC was named the SAS Team, comprising members from the various SEC departments. They are tasked with reviewing all documents created in this project and making the technical decisions.

The other portion of this paper describes the development of a Generic SAS Scope of Work (SAS SOW). This document contains the scope of work items standard to all SAS projects. This paper describes the SAS SOW development: the manufacturer surveys, the site visits, the presentations conducted and lessons learned during learning curve, where the data were collected for the document's development. Also mentioned are the commissioning requirements and SEC in-house standards which support this document.

The above two initial encounters of SEC with SAS has driven a company-wide introspection. Since the SAS implementation will be globally implemented, and the executive management has embraced its implementation, a decision to reorganize the SEC has been reached. This paper describes the new responsibilities identified with SAS implementation, from project conception to project cutover.

Future SAS plans are discussed: SAS implementation in the lower voltage substations, modification of existing standards/development of new ones, and prequalification of suppliers.

2. KEY WORDS

IEC 61850, Intelligent Electronic Device (IED), IEC 60870-5-103, Logical Node (LN), Substation Configuration Language (SCL), Station HMI, Station Bus, GOOSE, IREG-B, SNTP, Generic SAS SOW

3. INTRODUCTION

Energy service providers are continually faced with the challenge to provide their clients reliable power at competitive prices. Equipment failures, lightning strikes, accidents and natural catastrophes result to long service interruptions. For these reasons, the need to monitor and control substations and take necessary accurate and timely precautions has become of paramount importance to the utility operators. In order to prevent possible substation disruption from unexpected failures, a highly reliable, secure, scalable, robust and cost effective communication network that guarantees strict quality of service between the substations and their remote control center is vital. In this respect, substation automation, which is the creation of highly reliable, self healing power systems that swiftly responds to real time events with appropriate actions, has emerged to ensure the maintenance of uninterrupted power services to the end-users.
Substation Automation System (SAS) evolved in the mid-1980's from the initial proprietary-based SAS installations to the UCA 2.O based SAS installations, to the new generation IEC 61850. The legacy substation automation protocols and architectures typically provided only the basic functionality for power system automation owing to limitation of networking technology available during that period.

Process automation solutions are widely accepted for power systems. They are mostly based on a huge number of proprietary specifications or (de facto) standards. The future power systems will be smarter at the top smarter at the bottom, and permanently aware of the word around them. Utilities and vendors take the advantages of the new seamless use of the standards. And make the electric power system safe and more efficient than before. (Please refer to TC57 Reference Architecture Figure 1)[10]

The current generation of networking technologies and protocols has veered dramatically from the previous ones making possible design paradigms never been imagined. Protocols like TCP/IP, OSI standard, Ethernet network technology are among those that made new solutions feasible. These were coupled with the development of high speed computers and networking equipment as well as high speed media like fiber optics and twisted copper cables. With Intelligent Electronic Devices (IEDs), which convert the primary substation equipment into network nodes, a new paradigm of engineering the substation network emerged using a configuration language, called SCL (substation configuration language). As the substation network environment has been converted to one in an IT environment, installations of applications like those of security, network/ equipment redundancy, some discriminating utility operators, have either postponed substation automation implementation or sourced vendors willing to implement draft portions of the standards. In some cases, operators themselves cling to their in-house solutions pending approval of the draft parts of the IEC 61850.

But owing to a number of unresolved issues in the standard suite yet, like security, network/ equipment redundancy, some discriminating utility operators, have either postponed substation automation implementation or sourced vendors willing to implement draft portions of the standards. In some cases, operators themselves cling to their in-house solutions pending approval of the draft parts of the IEC 61850.

Unfamiliarity of utility personnel in the contract procurement, engineering, project construction management, testing, operation, and maintenance is another reason contributing to the reluctance of utilities to initiate substation automation implementation, a risky untrodden path for them. The hesitation of manufacturers to produce at competitive cost a new family of equipment and systems complying to the IEC 61850 is another reason utility operators are hesitant, too, to implement SAS. These manufactures have long been catering to existing standards like IEC 61970, ANSI, and IEEE. In addition, some have already been producing pre-IEC 61850 versions of their proprietary substation automation equipment.

4. BRIEFING ON IEC 61850

Saudi Electricity Company (SEC), the lone electricity provider in Saudi Arabia Kingdom, like any other utility company in the industry, is in continual pursuit of solutions to provide reliable cost-effective services to its customers. Response times to energy delivery failures caused by natural calamities, accidents, system breakdowns, operational negligence, and malicious activities top the list of perennial problems that the Company faces.
Interoperability is another issue unsettling SEC. While it is fact that vendors and system integrator proposals abound, the issue of interoperability of existing utility equipment with vendor-proposed equipment continually haunts the industry and makes solutions expensive to implement.

This is further complicated by incompatibility and inadequacy of various standards, not to mention the dragging approval of standards by members of standardization bodies, which membership counts chiefly from the utilities and suppliers, the latter being understandably protective of their existing proprietary technologies.

On the other hand, it behooves upon the vendors and standardization bodies, as well as the utilities, and the industry in general, to have one standard, an ironically painful wait for every entity.

Meantime, a utility company, whose services directly affect the mass of the energy users, is left with its own ways to strike strategic decisions at seemingly opportune time for its own economic survival and maintenance of commitment to its users, instead of waiting for the 'ideal' situation dictated externally by industry and/or standards completion. The company must take this calculated risk, while delivering quality services to its clientele concomitantly protecting the economic interests of its investors as well as employees.

It is within this context and complex situation that SEC has decided to implement substation automation, and implementing the technology with caution and awareness of industry developments. SEC's Pilot Project, which is now in its early stage of equipment manufacturing is moving satisfactorily and unhampered.

This paper intends to share this conference, the GCC CIGRE Power 2009, the industry, and the readers in general, the path that SEC has taken along the implementation of the substation automation technology in selective areas within its electrical network.

IEC 61850, "Communication Networks and Systems in Substations, is the core standard of the substation automation implementation framework SEC has embarked on in its pilot project. But is it safe to use the standard now?.

The Rationale behind the decision to embrace IEC 61850

The more than 4000 IEC 61850 implementations [1] that have been recorded globally is a testimony to the technology's acceptability, a proof to the viability of using IEC 61850 as a substation automation standard. And that it is now the opportune time for SEC, a traditionally conservative, utility company, to join the horde of initial users. Providing more confidence to SEC is the fact that members of the working group of IEC responsible for the development of the standard represent utilities and manufacturers aware of the age old industry problems of interoperability and lack of integrated substation communications. Upcoming is the release of IEC 61850 version 2, which shows the IEC's initiative to speed up the standard's perfection or completion.

Trends in the field of substation automation systems

To understand rationale behind the company's decision, it is necessary to briefly review the main features of IEC 61850-based substation automation, its evolution and the trends going on around the world.

To come up with an effectively optimized system and reduce costs, the on-going trend now has been the increasing integration of more functions into less number of devices. The function of monitoring, control and protection may now be combined into one common device, for example, at the bay level. This integration results in various functions previously held by separate departments into fewer departments. Today, the functionality provided by protection, control, and monitoring is not handled separately, but is integrated into one common and integrated system. This integration has been made possible with the advent of serial communication and networking technologies, as well as microprocessor technologies that enabled the development of multifunctional equipment.[3]

Before the introduction of microprocessor-based equipment and these recent communication technologies in substations, monitoring, control and protection had been handled separately by different pieces of equipment. This also resulted in responsibilities split in various disciplines or corporate departments. This also resulted in suppliers specializing in one type of equipment. With the deployment of serial communication in substations, the integration between monitoring, control, and protection started with the introduction of IEC 60870-5-103, as informative interface for protection devices.[2]

As IEC 60870-5-103 focused only on protection, the pressure increased to have more information exchange between all specialists involved in substation automation, and the need for a common protocol. This led to the birth of IEC 61850, Communication Networks and Systems in Substation, which functions to encompass all these trends and needs.
Core features of IEC 61850

The primary core feature of IEC 61850 is to provide interoperability of equipment in a multi-vendor environment in a substation [4] [7]. For example, SEC and other utilities have a requirement for Main-1 and Main-2 protection (Busbar, Breaker Failure and Feeder Protection) be provided at certain higher voltage levels (primarily 380 kV in SEC’s case) from different equipment manufacturers/equipment vendors. Prior to the implementation of IEC 61850 for data acquisition applications related to these relays/Protection IED’s, there may be used a core lower level standard (e.g. IEC-103), or proprietary schemes. As such, to integrate this Relay with an older, a different vendor (pre-IEC 61850) system, either protocol converters had to be used, or if IEC-103 was available (for both devices) the use of IEC-103 which had considerable limitations as compared to IEC-61850.

Another core feature of IEC 61850 which helps in multi-vendor interoperability, is the use of what is called a Logical Node (LN) Description which describes in generic terms, the functionality of a certain device (e.g. a Control Switch which is known as a CSWI Logical Node) which makes it very easy to integrate another SAS equipment manufacturer’s IED into an overall control and protection system contained as part of SAS. In order for the SAS equipment manufacturer to claim that his device is IEC 61850 compliant, the SAS equipment manufacturer must design and construct his hardware, software and firmware to meet the required Logical Node (LN) description requirements of IEC 61850 (though IEC 61850 does provide SAS equipment manufacturer’s and customer’s additional functionality as IEC 61850 optional features). [5]

A third major core feature is for the common development of common IEC 61850 code known as a Substation Configuration Language (SCL) which can support control and protection applications for a multivendor environment. Although developing raw IEC 61850 SCL code is cumbersome, and can be error prone (since it generally uses command-line like features), most SAS equipment manufacturers now offer SCL shortcut tools (e.g SEL with its SEL accelerator, ABB with its PCM 600, etc.) which is Graphic User Interface (GUI) based and based on the GUI tools, generates the raw SCL code which can, in some cases can generate SCL code on a competing SAS equipment manufacturer’s IEC 61850 based equipment. It is also noted for the SCL development process, virtually all SAS equipment manufacturer’s have SCL interpretation tools which can interpret raw SCL code for errors which may occur as part of the SCL development process. [6]

Finally, another major core feature of IEC 61850 include use of what is known as the OSI 7 Layer Stack, with common applications used as part of the OSI 7 Layer Stack (e.g. for OSI Layer 2-Ethernet is used, for OSI Layer 3 and 4-TCP/IP is used, and OSI Layers 5 to 7-MMS is used). This does also support multi-vendor interoperability (disturbance) recorders, but as part of an integrated SAS, this functionality can be performed by an integrated Disturbance Fault Recorder function as part of the IED’s and Station HMI (Human-Machine Interface) equipment. Furthermore, limited intelligence can be downloaded as part of the Station HMI to perform automatic switching sequences, and other functions, which cannot be done before with most conventional stand-alone systems.

Benefits to the utilities

As stated before, the major benefit that IEC 61850 offers is the multi-vendor interoperability under IEC 61850. Such multi-vendor interoperability makes it easy to integrate equipment from multiple SAS equipment manufacturers into one system to meet various utility customer’s requirements.

A second major benefit of IEC 61850 provides for considerably reduced wiring and parts count. In the past, with stand-alone SCADA RTU’s and stand-alone SOE RTU’s there may be a duplication of points/signals (with the identical point/signal description going to an input to a SCADA RTU, and then to an SOE RTU) with such duplication of wiring/inputs resulting in considerable additional cost [9]. Furthermore, wiring can be reduced further if GOOSE messages are used, since wiring for the same condition to two, or more IED’s does not have to be duplicated (e.g.-this saves considerable wiring if GOOSE interlocks are used, since GOOSE signals can be sent from one IED to another to indicate the state of a particular device that have to be reported to two, or more IED’s).

A third major benefit is the greater data acquisition and control capability of the Station HMI level. This did not exist before with stand-alone equipment in conventional substations, where for example, fault recording was performed by stand-alone fault.

The fourth major benefit is also in terms of supporting combined control and protection functionality into one IED unit which can save considerable space especially at the lower voltage levels where switchgear is relatively compact, and there is not much floor space for separate control and protection “boxes” (combined control and protection functionality is available with many SAS equipment manufacturer’s offerings for units provided at the 13.8 kV level). [8]
In summary, the major benefits are cost reduction through reduced duplication of wiring, and reduction of equipment which provides the same functionality, and greater data acquisition and control functionality.

**Impact on substation specification**

Given that Substation Automation Systems (SAS) are generally integrated systems which integrate Substation Control, Data Acquisition, Sequence of Events Recording, Disturbance Recording, Protective Relaying, Substation Communications, Display, and Annunciation systems, there is a major impact in the development of substation control, data acquisition, and protection systems which used to be served by stand-alone units. In the impact on substation specification development, the systems developer must be knowledgeable and cognizant of all areas of SAS, and related discipline engineers (such as Protection), must also be knowledgeable in all areas of SAS substation specification development.

Ideally, the SAS system specification developer should have considerable protection experience and training, SOE experience and training, SCADA experience and training, substation communications experience and training, network experience and training, IEC 61850 standards experience and training, and finally HMI experience and training.

Furthermore, conventional substation systems specifications must be modified to accommodate SAS, and modifications made to eliminate older stand-alone SCADA RTUS’s, SOE RTU’s, Protective Relays, etc. to accommodate SAS equipment additions.

**Vertical communication [2]**

From SEC’s experience in the communications infrastructure and levels of hierarchy of SAS, most SAS equipment manufacturers tend to use a level hierarchy comprising four control levels which are as follows:

- Mimic (Electromechanical Control) Level-
  Lowest
- Control IED Level
- Station HMI Level-Highest Level at the Substation
- Power Control Center Level-Highest

Generally, most SAS equipment manufacturers do only allow control for a switchgear item from one level only, but in rare cases control of switchgear can be split between certain levels (e.g. one part of the substation may be provided control from the Power Control Center, and the other part can be provided control from the Station HMI). Although for some SAS equipment manufacturers this can be made possible, SEC discourages this practice (except for maintenance) since no clear levels of control can be provided for tagging/operations purposes.

**Horizontal communication [2]**

For the horizontal communication requirements, basically, in the SEC survey performed by most SAS equipment manufacturers, there are two horizontal communications paths that are used.

The first horizontal communications path that is used is what is known as the **inter-bay bus**, which for IEC 61850 based systems, MUST be configured as per IEC 61850 requirements. This is due to the situation that, under IEC 61850, there are priority communications requirements based on the urgency of the message that is to be transmitted and received. For example, GOOSE messages which are used for interlocking signals, and certain inter-trip signals, must have a very fast speed and must take a higher priority over such messages as transfer of data acquisition signals (e.g. transfer of disturbance records). IEC 61850 has very well defined standards in terms of implementation of priority signals, and transit time for all IEC 61850 signals, where other general standards do not. As far as SEC’s survey of the current market, all SAS equipment manufacturers DO implement IEC 61850 on their inter-bay bus, and SEC specifications in this regard require the use of IEC 61850 for this application.

The second horizontal communications path is known as the **Station Bus**, and depending on the SAS equipment manufacturer, may be implemented under IEC 61850, or through other means (it is noted that for the station bus, if a SAS equipment manufacturer does not implement this under IEC 61850, then virtually all SAS equipment manufacturers (who do not manufacture an IEC 61850 station bus) offer this requirement through standard TCP/IP). On the Ma’aden project, Station Bus requirements are offered by the Contractor by standard TCP/IP, and not IEC 61850.

**Goose messages**

One of the major advantages of IEC for an Electric Utility (as indicated before) is that there can be a considerable reduction in wiring (and related reductions in wiring labor costs) for SAS installations which use GOOSE messaging capability. For interlocking conditions related to closing of an earthing switch, interlocking data can be obtained by hard-wired means, or messages transferred (for interlocking information) through GOOSE messages. If GOOSE messages are employed, this can eliminate multiple distribution wiring from an IED which generates this interlocking information to multiple external IED’s which can result in considerable cost savings, as duplicate wiring does not have to be run, and interlocking data can be transferred between IED’s through the use of GOOSE messages example, for a breaker and one-half scheme, for the
In SEC's case, what SEC has decided to do in this regard, is to build the initial SAS equipped substations with two interlocking schemes, with the first scheme being hard-wired (use of contacts/electromechanical relays), and the second scheme being through software/GOOSE. In the case of Ma'aden, the scheme is as such that the final interlocking filtering process is through hard-wired means (as at the current time, hard wired schemes tend to be the most trusted), but the first interlocking path (using software/GOOSE) does an initial check of interlocking conditions. However, on later projects, as SEC does gain trust in the operation of software/GOOSE interlocking schemes, there may be a requirement to trust and rely upon software/GOOSE as the interlocking scheme of choice, and eliminate the use of hard-wired interlocks.

Also, GOOSE messages can be used for other applications, such as forwarding of inter-trip signals within the substation only (inter-trips between substations will be defined in a future version 2 of IEC 61850) and other applications.

Finally, due to the criticality of GOOSE messages the use of GOOSE messages requires a very high reliability for the communications path for the inter-bay bus. Basically for future projects, SEC requires the implementation of redundant inter-bay bus schemes which will comply with the future IEC 61850 Version 2 requirement in this regard.

Time synchronization

One of the key functions of SAS is with regard to time synchronization of all components of the SAS installation. Generally, in the survey which SEC has performed with various SAS equipment manufacturers, time synchronization can be performed through the use of IRIG-B signals (which provides a maximum of 1 ms deviation from real time for SAS components), and the second method is through use of SNTP (System Network Time Protocol-which provides a maximum of 5 ms deviation from real time for all SAS components).

For IRIG-B, again, the advantage of IRIG-B is that there is a better time resolution deviation with IRIG-B. but the major disadvantage of IRIG-B is that dedicated hard-wired IRIG-B signal port inputs must be available for all SAS equipment devices (e.g. IED's Station HMI equipment, etc. which may not be implemented by all SAS equipment manufacturers). Also, due to this disadvantage elaborate clock distribution schemes must be developed and provided, and can be very costly as a result of the implementation of the distribution schemes.

On the other hand, SNTP (Simple Network Time Protocol) has one advantage that SNTP can distribute GPS Clock receiver information through the entire existing networks (IEC 61850 and TCP/IP networks), eliminating special port requirements for SAS equipment (as SNTP signals are transferred by the inter-bay bus to the specific SAS devices.). Another advantage of SNTP is that SNTP does NOT require the use of a considerable amount of additional clock distribution schemes (as IRIG-B does), which can result in cost savings. However, SNTP does have a major disadvantage in that SNTP requires a deviation of a maximum 5 mS from "real time" for SAS devices generating time stamp information for records purposes.

In the case of Ma'aden, SEC did accept the use of SNTP with the condition that all SAS devices deriving time stamp information from SNTP shall see a maximum of 1 mS deviation from real time for time stamping information, which the Contractor agreed to comply with.

Ethernet architecture considerations

Given that IEC 61850 is in the relatively early stages of standardizing fault-tolerant Ethernet architecture, on early SEC SAS projects (e.g. Ma'aden), SEC has accepted non redundant Ethernet architecture in specific rings for each voltage level. This architecture allows for some fault-tolerant features, such as path switching if there is a fiber cable break in the inter-bay bus, but does not provide for fault tolerance of the Ethernet architecture if there an Ethernet Switch failure. In the case of Ma'aden, to get around this problem, very high reliability substation hardened Ethernet switches were used, and which can be easily replaced with an entire replacement Ethernet switch in a very short period of time (e.g.-five to ten minutes).

However, for future SAS projects, as IEC 61850 will be defining a redundant Ethernet architecture (using the principles of IEC 62439) , SEC is now specifying the use of the version of IEC 62439 which is planned to be implemented under IEC 61850 Version 2.

SEC have surveyed SAS equipment manufacturers pertaining to the interest for developing IEC 61850 Version 2/IEC 62439 redundant products, and at least two SAS equipment manufacturers have expressed an interest in developing product and software/firmware in this application, and it is expected that further SAS equipment manufacturers will follow the lead of the two SAS equipment manufacturers in this regard.
Main aspects of system design

In the main aspects of SAS system design, probably the most important and key aspect is SAS installations MUST be designed and constructed with a very high degree of availability and reliability. SEC requirements in SEC specifications call for a 99.995 percent availability for the SAS System design. Furthermore, SEC specifications require a 20 year MTBF figure for all non-redundant portions of the SAS (e.g control IED's, etc.) To meet this availability requirement, redundancy of key components in the SAS is specified (e.g. Station HMI equipment, communications gateways, etc), and where required the SAS Equipment manufacturer must design his system taking this availability factor in this account.

Other main aspects of SAS System Design will generally involve the integration of control, protection, data acquisition, interlocking systems, substation communications, time synchronization, annunciator and alarm systems into one cohesive IEC 61850 compliant installation. It is due to this reason that SEC is now requiring SAS equipment suppliers/system integrators be able to design and construct integrated comprehensive SAS installations, and SAS Contractors/Subcontractors will be fully responsible for delivering and commissioning integrated SAS installations, and not rely on a “piecemeal” approach (which was done in the past with “stand alone” equipment.

SEC GENERAL SAS DESIGN STRUCTURE

In general the Substation Automation Structure based on IEC 61850 consists of three levels (see Figure 3):

1. **Station Level**
   - The Station Level provides the human machine interface (HMI) as a central place for Substation Operation. This is normally located in a central room (control room), which should be shielded against electromagnetic disturbances from the switchyard. Further all general purpose hardware, Displays/Screens and printers are concentrated on Station Level. All general management and station level functions like event logging & printing, archiving and historical data storing are located at Station Level.
     - Station HMI – It serves to operate and supervise the S/S. Industrial grade workstation running windows XP, or other proprietary operating system along with applications software.
     - Printer(s) – For Alarm, Events and Reports. They may be Laser and/or dot-matrix printers.
     - Engineering Workstation –Industrial grade workstation running windows XP, or other proprietary operating system and it is mainly used for engineering of SAS. It also runs engineering tools.
     - GPS Clock Receiver(s) – For Time synchronization.
     - Communication Gateway(s) – It provides data access and control from NCC. The data transfer usually involves the protocol conversion for specific protocol used by NCC (ex. IEC 60870-5-104).
     - Front End Station Computer(s) – For Supervisory and Control functions. These are industrial grade hardware running Windows 2003 Server or other operating system and the application software (ex. MicroSCADA Pro, PACIS, etc.). which may include Fault Location capability, Transient Fault Recorder functionality, and a considerable amount of Protection features in a multifunctional Bay Level Protection IED(s).
     - Alarm Annunciator – For all station relevant alarms from the fire fighting system, the battery charger etc. are connected to this annunciator.
     - Station Alarm Device – It is used in SAS to resume and show associated alarms. Its main purpose is to call attention to abnormal process conditions. It presents exchange the active alarm classes (grouped process alarms) of the SAS and the watchdog functions of the station computers.

2. **Bay Level**
   - Usually close to the switchgear and allows the operation with one bay only.

3. **Process Level**
   - Provides the interface between the SAS and the switchgear.

(Figure 3)
- **IEC 61850 LAN** - It is the interbay bus for real time data among Bay Level (Control & Protection) IED(s) and this interbay bus also connects the bay devices at this level to the Station Level. The LAN is conformant to IEC 61850-8-1 standard. It consists of the industrially hardened Ethernet Switches and the Fiber Optic links.

- **Station LAN** – The Station LAN based on IEEE 802.3 and TCP/IP is used to interconnect the subsystems at the station level. Station HMI, Front End Station Computers, Engineering Workstation, and Printers etc are connected to this LAN. The Station LAN consists of the industrially hardened Ethernet Switches and Copper/Fiber Optic links.

- **Others** (DC/AC Inverters, Media converters, Large LCD Display & Modems).

**Bay Level**

- **Bay Level Control IED(s)**
  Bay level control function allows to operate a bay locally. All bay related measurands (voltage, current, power, frequency….), alarms and relevant state information are displayed here, and control commands can be initiated by means of a HMI, which is integrated in the bay control unit (BCU) as a screen with functional buttons. Also additional functions may be included in the Bay Level Control IED(s), such as synchro-check, synchronization (for Power Plant SAS installations), Pole Discrepancy protection functions, Auto-reclosing, PT Fuse Fail functionality, GOOSE interlocking, etc. Also at this level there is a mimic panel (Local Control Mimic) generally inside the LCC which provides for emergency control functions in the event of failure of the Bay Control Level IED.

- **Bay Level Protection IED(s)**
  The object protection is typically also located on bay level, as the classical objects like lines, transformers and generators are all allocated to switch bays, so that they can be isolated from the substation busbar by tripping the corresponding circuit breaker. Numerical protection relays have a LCD based built-in HMI, which allows checking the last events and the activated protection parameters. Additionally some SAS equipment manufacturer’s Bay Level Protection IED(s) provide additional data acquisition functionality which may be included in the Bay Level Protection IED(s).

**Process Level**

It provides the interface between the SAS and the switchgear. For now, the process level is still implemented in the conventional way (using copper connections) so no change in expected in the system at the process level.

5. **MAAEDEN PILOT PROJECT EXPERIENCE**

**Project Execution Plan**

With respect to Ma’aden, the original plan was to provide this as a customer-owned substation, which the customer (Ma’aden) would have operated and maintained the entire substation, from the 380 kV side of the substation, down to the station service voltage level at 13.8 kV. In early, 2008, however, an agreement was reached with SEC Management for SEC to take over the operation of the 380 kV voltage level (which is configured in a breaker and one-half scheme). As the original design of the substation provided for conventional (non-SAS) scheme but the concept that was changed to Substation Automation (SAS). Under the original concept, there was one SAS installation to cover all voltage levels, but as time progressed with the separation of responsibility, two SAS installations were provided for the substation, with one SAS installation for the 380 kV side (to be eventually operated by SEC), and one SAS installation for the 115/13.8 kV side (to be eventually operated by Ma’aden).

Although the Ma’aden contract is one contract (to be managed by Ma’aden/Worley-Parsons), any items related to the 380 kV portion of the substation are closely coordinated with SEC, and with SEC providing final approval for the portions of the substation regarding the 380 kV side (including the Substation Automation System (SAS)).

Currently, there is a target for energization of the 380 kV side of the substation by September, 30, 2009, and generally the project is now proceeding on schedule (although in the early stages of the project (especially with regard to SAS portions) there was a slip in the schedule, but there is considerable “catch up” activity). It is anticipated that the September 30, 2009 energization date will be met.

**Factory Acceptance Testing (FAT) Procedures/Plan**

For the SAS for the 380 kV side of Ma’aden 380 kV substation, there were a numerous amount of Factory Tests, and Factory Acceptance Tests which were performed as part of the SAS FAT process. Basically to familiarize SEC with the process of the Factory Acceptance Testing process, the Contractor did provide considerable training on both the system, and documentation review training.
This training was held both in-Kingdom (within Saudi Arabia), and in ABB’s facilities in Switzerland. During and after the training on the SAS, there were two levels of FAT, with the first level known as the LCC FAT (Local Control Cubicles FAT) which was conducted in early February, 2009 (which covered components in the LCC’s, including Mimic Panels, Bay Control Units (BCU-or Control IED’s), Meters, Terminal Blocks, auxiliary relays, etc.). The second stage of the FAT process was called the SAS System FAT, and covered Busbar Protection/ Breaker Failure Protection, General SAS components and other integrated SAS items (e.g. inverters, GPS receivers, etc.) and which was performed in mid-March, 2009. All items related to the LCC Cubicles have been resolved, and clearance is underway for items relating to the SAS System FAT.

Testing/Commissioning Activities/Procedures

It is planned to start the Testing/Commissioning activities for SAS related items during the months of July, August and September, 2009. Due to the process of requiring traceability throughout the testing process (e.g. “cradle to grave” traceability), it is hoped that there will be minimizing the repeating/replication of requirements. For example, SEC Operating tests during the overall testing/commissioning process as a result of traceability of past tests, thus reducing the overall testing/commissioning time. However, given that this is the first SAS installation which SEC will operate, it is hoped that as part of the testing/commissioning activities, new SEC players will be involved, so due to this, some aspects of the testing/commissioning process may be extended. Also, testing/commissioning will involve testing all components of the SAS, including all control and protection functions of SAS, as well as auxiliary functions (inverters, GPS receivers, Communications Gateways, Station HMI computers, workstations, etc.).

Learning Points

Given that Ma‘aden is the first SAS installation which SEC will eventually operate the 380 kV SAS, there are many learning points that have been encountered as part of the SAS implementation process. Some of the learning points/pitfalls/problems which have been encountered include the following:

• Lack of formal training in the early stages of the project For this, many of the items which could have been learned (and have actually been learned) as part of formal training were picked up in the late stages of the project, causing possible considerable delays. For example, during the early stages of the project, the importance of timely information needed for the Contractor to develop his SCD (Substation Configuration Description) files, and related CID (Configured IED Description) files was not explained early by the Contractor, and was only picked up by SEC during the formal In-Kingdom Training. To resolve this for future SAS related projects, SEC is now requiring in future SAS Scopes of Work that as part of the overall SAS Training Plan for each contract, that “Documentation Review” Training is to be held before the start of the Base Design Review Stage. During this portion of the training, deficiencies on an overall SAS installation and key requirements which are needed by the Contractor can be identified early, so that SEC can provide this timely information so as not to delay the overall design process.

• Unfamiliarity with SAS from key SEC departments Given that the concepts of SAS is relatively new with many of the key SEC Operating Departments, this has caused a considerable problem of adaptation of personnel with key SAS personnel are very familiar with the operation of hard-wired interlocks, but software/GOOSE interlocks is a brand new concept for these personnel, and there is currently may not be enough trust in software/GOOSE interlocking concepts or systems. It is for this situation that a series (parallel) scheme of software/GOOSE interlocks along with hard-wired interlocks, with the hard-wired interlocking being the last filter in the interlocking chain. However, in the future, as SEC personnel, gain further experience with SAS as well as further familiarity with SAS it is eventually envisaged to phase out hard-wired interlocking schemes and rely solely upon software/GOOSE interlocking schemes

• Lack of SEC Standards related to SAS and adaptation of current SEC standards related to SAS; Given that SAS is a relatively new concept for SEC, there has not been quite a bit of standards development activity related to SAS installations within SEC. Currently the only major SAS standards development activity is development of a Generic SAS Scope of Work to be used for future SEC substations equipped with SAS. Further plans are being considered by the SEC to develop new SAS Materials, Engineering and Construction Standards, as well as development of an Approved Materials List, as well as a listing of approved SEC SAS Contractors/Subcontractors. It is expected that this process will be finalized in the next two to three years.
• Learning from other Electric Utilities and SAS equipment manufacturers: It is noted that many Electric Utilities worldwide have already installed a considerable number of SAS installations (including IEC 61850 based installations), as part of the overall learning process, SEC personnel have attended site visits to various operational SAS installations, including in Electric Utilities in Bahrain, and other locations. Further visits are planned as SEC coordinates with various SAS equipment manufacturers as time goes on.

• Keeping Current with Industry Standards related to SAS: As part of determining the “State of the Art” as it relates to SAS, SEC has been heavily involved with review of current industry standards related to SAS. Most importantly, review of new versions of IEC 61850 is key, as Version 2 of IEC 61850 will have to be performed as Version 2 gets rolled out.

• Close coordination within SEC departments related to SAS: As SAS installations require an interdisciplinary approach to engineering/design, construction, testing/commissioning and operations, for a number of systems, there needs to be close coordination between the various SEC departments. For this objective, SEC has developed a SAS Team (see below), and is now developing a strategic plan which will involve and be coordinated with many SEC departments.

SEC Executive Management Endorsement

For the Ma’aden project, during the first phases of the SAS for the project, SEC Executive Management was very heavily involved with regarding the endorsement of SAS for the 380 kV side of the Ma’aden 380 kV substation (which, SEC will eventually operate and maintain). SEC Executive Management has worked very closely with the customer (Ma’aden) in this regard in the past, and will expect to work closely with Ma’aden as it pertains to turnover of the 380 kV substation portion (including the SAS) to SEC.

6. GENERIC SCOPE OF WORK SUBSTATION AUTOMATION SYSTEM

Generic Scope Rationale for of Work Development

As part of the process relating to engineering, design documentation review, construction, testing/commissioning and ultimate energization of substations SEC is generally responsible for development of what is known as a Scope of Work/Technical Specification document for substations. As part of the substation Scope of Work/Technical Specification development, in the past, “stand-alone” control, data acquisition, and protective relaying systems have been specified to facilitate the engineering, design documentation review, construction, testing/commissioning, and ultimate energization of these “stand alone” systems.

It is noted that in the SEC development for all substation Scopes of Work/Technical Specifications, the main objective is to write a specification that is as competitive as possible to support the competitive bid process while maintaining overall operational and maintenance objectives for SEC substations.

Based on this, SEC did decide that this process should be extended to future Substation Automation Systems to facilitate the transition to these SAS based substations.

The Development Process

Basically in the development process, SEC has taken a parallel (two fold) approach with regard to completing the development of the SAS Generic Scope of Work. This is described as follows:

The first approach is for an SEC review of existing control, data acquisition, and protective relaying requirements as it pertains to current “stand alone” systems, and, in consultation with various SEC departments, and applicable standards (e.g. IEC 61850), adapt the functional requirements of these-

SAS Team

With regard to the overall SAS implementation plan for Ma’aden and other SAS related projects, SEC has formed what is called a SAS Team which is multidisciplinary in approach (comprising of many members from different SEC departments), and for the Ma’aden project, the SAS Team (Substation Automation System Team) was very heavily involved during the Base Design Stage and Base Design Review stage of SAS, reviewing many of the aspects of SAS, including control and protection philosophies, basic construction of SAS, and interfacing of SAS with external equipment/systems (e.g. external SCADA Master Stations, SOE Master Stations, and other external systems/equipment). Also, on future projects, it is anticipated that the SAS Team will be considerably involved with assisting in the development of standards, and review of equipment offerings, and overall SAS systems offered by various SAS equipment vendors/systems integrators.
“stand alone” systems into integrated SAS solutions which will be acceptable to SEC in the future. As part of the development of these integrated SAS solutions, additional requirements which may not be included in conventional “stand alone” systems which are peculiar to SAS (e.g. Automatic Switching Sequences) are included in the development of the Generic SAS Scope of Work

The second parallel approach involves a survey of various SAS equipment manufacturers/SAS system integrators to see what the competing SAS equipment manufacturers/SAS system integrators offer in terms of IEC 61850 based products pertaining to SAS, as well as major similarities and differences between IEC 61850 based systems between the competing SAS equipment suppliers/system integrators. For this process, SEC has selected a core group of leading SAS equipment manufacturers/SAS System Integrators serving the Gulf Cooperation Council (GCC) market.

Under the total approach, it is noted that SEC does plan to develop two separate SAS Generic Scope of Work documents, with one Generic SAS Scope of Work being developed for 380 kV substations, and the second SAS Generic Scope of Work being for 132 kV (and lower voltage level) substations. There will be minor revisions between the documents, with the 132 kV (and below) Generic SAS Scope of Work emphasizing the electrical distribution nature of the substation, and the 380 kV Generic SAS Scope of Work emphasizing the bulk power nature of SEC 380 kV substations.

The current status of the Generic SAS Scope of Work Development Process, involves is that SEC has completed the survey of the various SAS Equipment Manufacturers/System Integrators, and based on the SAS equipment manufacturer’s inputs, and internal SEC development process and is anticipated to release the final draft of the SAS Generic Scope of Work for internal SEC SAS Team review/comment by the end of June, 2009

Annual Updates

As indicated previously, SEC is currently in the process of finalizing the Generic SOW documents for SAS, and once finalization is completed, it is planned to develop the Generic SOW documents for SAS as being a final SEC Approved Engineering Standard. The timeline for implementation of these Generic SAS Scope of Work documents into an SEC Approved Engineering Standard will be in late, 2009.

After approval of these Generic SAS Scope of Work documents into SEC Approved Engineering standards, it is expected that annual updates to these standard SAS Generic Scope of Work documents will be required due primarily to the following four factors:

- Ongoing evolution of the IEC 61850 standard. It is noted that, according to IEC, IEC 61850 will be a continually evolving standard. However, evolution of IEC 61850 will insure “backwards” compatibility to earlier versions of IEC 61850, but will provide enhancements to the IEC 61850 standard as they become available. For example, part of IEC 61850 Version 2 will provide enhancements which are key to the reliability of substation communications networks by providing a redundant IEC 61850 Ethernet standard scheme.

- SEC considers this vital for SAS installations operating at the 380 kV voltage level operations.

- Ongoing experience with regard to SEC and other electric utilities engineering/operating/maintenance experience with IEC 61850 based SAS installations. In this respect, SEC does expect to energize its first 380 kV SAS based substation installation (Ma’aden 380 kV) in the fall of 2009, and during 2010/2011, there will be various 132 kV and below substations which will be implemented with SAS. Furthermore, SEC will be in constant communications with other electric utilities who are implementing (or who have had implemented) SAS, and also will obtain ongoing experience of engineering/operations/ maintenance of their SAS based installations. Based on this combined ongoing experience, annual refinements/updates will be needed for the Generic SAS Scopes of Work where it is deemed to be necessary.

- Annual survey of SAS equipment manufacturers/SAS System Integrators to determine improvements to their equipment (both based on improvements on IEC 61850, as well as any SAS equipment manufacturers/ SAS System Integrators specific additional features which do not conflict with IEC 61850). Surveys of the SAS Team to determine what should be included in the Generic SAS Scope of Work annual updates based on the other three items indicated above

It should be noted that, once the initial Generic SAS Scope of Work documents are finalized and approved as an Approved SEC Engineering Standard, this SOW annual update requirement will no longer be the responsibility SAS Team, but will the responsibility of SEC Transmission Standards and Specifications Department.
7. SEC SAS FRAMEWORK

Aligning of various SEC disciplines according to SAS structure

In this activity, internal SEC evaluation has been performed with regard to conventional (non-SAS) Substation Control, Data Acquisition and Protective Relaying systems and the organizational framework for planning, engineering, construction supervision, test/commissioning, and operations/maintenance of these conventional systems. As part of this internal SEC evaluation, similar systems in SAS were looked at/reviewed, and where it was deemed to be possible, a one-to-one correspondence between non-SAS (conventional) systems and SAS components/installations was performed, where possible. Once this was completed, boundaries were set, and proposed details of responsibilities were provided within an internal SEC document. Further information in this regard appears below.

Setting boundaries of functions and responsibilities and detailing of responsibilities

Based on the above, SEC has proposed the setting of boundaries and responsibilities pertaining to planning, engineering, construction supervision, test/commissioning, and operations/maintenance of SAS based installations. Although this is currently in routing to SEC Executive Management for final approval by SEC Management, some of the initial highlights of these boundaries and detailing of responsibilities is as follows:

- For general planning and engineering responsibilities for SAS installations at new/existing 380 kV substations, (and when included as part of a 380 kV Scope of Work interconnected lower voltage substations) this will be the responsibility of SEC Transmission Asset Development Department.

- For general planning and engineering responsibilities for SAS installations at other substations (not indicated in the previous bulleted item), this will be the responsibility of the respective SEC Engineering and Design Division (SEC E and DD Department).

- For all planning and engineering activities for SAS, the various SEC operating and standards departments will be interfaced with, including SEC SOCD, SEC SMD, and SEC TSSD.

- For Testing and Commissioning activities, on initial SAS installations, the applicable SEC Operating departments will be involved with Test/Commissioning witnessing, but as SEC Commissioning Services Department (SEC CSD) becomes more familiar with SAS, this activity will eventually be turned over to SEC CSD for later SAS projects.

- Operations and Maintenance activities will be shared for SAS between SEC SOCD (Systems Operations and Control Department) and SEC SMD (Substation Maintenance Department).

As highlighted in this paper, for SAS Standards Development and Generic SAS Scope of Work Updates, this will be performed by SEC Transmission Standards and Specifications Department (SEC TSSD).

Finalization of SEC SAS Strategic Plan

It is noted that all items indicated in this section (SEC SAS Framework) will be identified as part of the SEC SAS Strategic Plan, which is currently being routed through SEC Executive Management at this time.

8. STRATEGIC IMPACT ON SEC OPERATION

Reorganization of current SEC departmental functions as SEC migrates to new SAS equipped substations, and retrofits existing conventional substations to SAS

Due to the limited number of SAS installations that SEC is having at this time (two 380 kV substations in 2009-2011, and approximately four lower voltage substations in that same time period), there is no current plans to reorganize operations and maintenance functions within SEC for the initial SAS equipped substations indicated in this paragraph. However, as more SAS installations take place and as SEC and other electric utilities gain more operational and maintenance experience with SAS, SEC is not ruling out possible reorganization of operations/maintenance functions to take advantage of SAS’s integrated approach to substation control/protection/data acquisition and metering. SEC notes that as IEC 61850 based SAS installations have only been in existence for a limited period of time (about five years), there will be much orientation provided as part of the early SAS installations before reorganization is to be considered.

Recognition of cost/benefit analyses and improvements of SAS equipped substations compared to conventional substations
Theoretically, SAS can offer considerable reduced costs and improved benefits as compared to conventional substations. Wiring can be considerably reduced, there can be combined protection functionalities into one protection IED (and possibly combined control/protection functionalities into a combined control/protection IED), better reporting of events, elimination of "stand alone" boxes and other improved benefits of SAS as compared to conventional installations. It is hoped that for both the ongoing SAS Installations at Ma’aden, and JEC 380 kV substation, and future SAS installations, these reductions in costs and improvements in benefits can be documented and identified to SEC Management to support improvements in operations and maintenance of SAS equipped substations as well as for future SAS designs/engineering. This will be performed on an ongoing periodic basis within SEC.

Full integration of control, data acquisition, metering, and protection into one SAS installation

As stated before, SAS installations are fully integrated installations which encompass control, data acquisition, metering and protection functionalities into one installation. In terms of addressing the strategic impact on SEC Operations of SAS installations such full integration capabilities must be reviewed to see how this could be tailored to existing and planned SEC Operations of SAS installations.

9. TRAINING

Seminars/Workshops/Presentations by various SAS vendors/manufacturers/system integrators

Throughout the years of 2007, 2008, and 2009, various members of the SEC SAS Team (SAST) have been involved with seminars/workshops/presentations provided by various SAS vendors/manufacturers/system integrators. These SAS vendors/manufacturers/system integrators have included major manufacturing companies as well as suppliers of supporting equipment for SAS installations (e.g. Ethernet Switches, etc.). Training provided by the Seminars/Workshops/Presentations for the SAS vendors tended to be more informal in nature which generally states concepts related to SAS for each of the SAS equipment vendor’s products, and IEC 61850 functionality. Also, integration concepts were also covered with the various SAS equipment vendor’s offerings, and comparison with other competing SAS equipment vendor’s installations.

Training sponsored by Ma’aden

Given that Ma’aden is the first SEC 380 kV substation equipped with SAS, there were agreements between Ma’aden and SEC Executive Management to require Ma’aden and the Contractor to provide extensive training related to SAS for the Ma’aden project. Both In-Kingdom Training and Out-of-Kingdom Training was provided, and which provided or will provide the following training requirements/concepts:

- **Documentation Review Training for SAS equipment** (In-Kingdom-held in November, 2008). This training encompassed concepts related to specific details related to ABB MicroSCADA, Ethernet Switches, IEC 61850 concepts related to SAS, IED’s used for Control and other matters, configuration of equipment, and other SAS related items. This training was separate from the training for the Protection Related to SAS (see below).

- **Documentation Review Training for Protection equipment related to SAS equipment** (In-Kingdom-held in November, 2008). This training encompassed concepts related to specific details related to the ABB REB 500 BBP/Breaker Failure Protection Relays and Siemens 7SS52 BBP/Breaker Failure Protection Relays, and their integration into SAS.

- **FAT Acceptance Training related to SAS and Protection related into SAS**. (Out-of-Kingdom held in the first quarter of 2009) This training encompassed concepts required by SEC to understand concepts related to the Factory Acceptance Testing for both the SAS components as well as the Protection IED’s integrated into the SAS.

- **Substation Operator Training related to SAS** (In-Kingdom-planned by August, 2009). This training will encompass SAS Operations training as it relates to Substation Operators/Network Operators, which will explain operation related to MicroSCADA, Control IED’s, Mimics and other auxiliary equipment.

- **General Operations and Maintenance Training** (In-Kingdom-planned by August, 2009). This training will encompass for detailed Operations and Maintenance training of all SAS components, including routine and preventative maintenance of SAS components, configuration of equipment, and troubleshooting/fault location concepts. This training is intended to be attended by SEC personnel who will eventually operate and maintain the SAS.
installation on the 380 kV side of the substation.

It is noted that given the general satisfaction of the training sequence indicated above, in future Generic SAS Scopes of Work, similar training concepts will be identified in the training Scopes of Works.

Site visits to SAS equipped substations

Throughout the SAS development and implementation process, various members of the SEC SAS Team have visited, or will be visiting various SAS equipped substations both within the GCC region, and worldwide. These site visits have been arranged between SEC, various SAS equipment vendors/manufacturers/systems integrators, and customer utilities which have already operational SAS installations. Similar to the training provided by the seminars/presentations provided by the SAS equipment vendors/ manufacturers/systems integrators, this training (attributed to site visits to SAS equipped substations) tends to be more informal in nature, stressing overall architecture of the operational SAS installations, benefits/drawbacks for SAS, and demonstrations of SAS equipment operations. Primarily the site visits in the past have stressed SAS installations in GCC, but future plans will involve site visits to international installations during the next year.

Technical exchange meetings/workshops with Saudi ARAMCO

As part of the support of training for the various members of the SEC SAS Team, there have been technical exchange meetings/workshops with Saudi ARAMCO. It is noted that during these technical exchange meetings/workshops, that Saudi ARAMCO’s approach to SAS tends to be for lower voltage substations (generally 66/69 kV and below), and that Saudi ARAMCO’s requirements for SAS tend to be slightly different than SEC (Saudi ARAMCO tends to focus on SAS for internal Saudi ARAMCO’s requirements only, which may include integration of their SAS with various Saudi ARAMCO Plant Control Systems, whereas SEC may have to interface in more detail with other customers in their current and future SAS installations). But common approaches between SEC and Saudi ARAMCO have been ascertained as part of these Technical exchange meetings. Again, training obtained by these Technical Exchange Meetings tends to be more informal and general, and does tend to stress overall concepts related to planning/engineering, operations and maintenance of SAS installations.

10. FUTURE STRATEGIC PLANS

Initial rollout of SAS for new SEC 380 kV substations

For 2008 and 2009 projects, there are two (2) 380 kV substations which will be implemented with Substation Automation Systems (SAS). Both these 380 kV substations are customer funded 380 kV substations, which are described hereafter:

- Ma’aden 380 kV Substation at Ras Az Zawr-(2008 project-funded by Ma’aden and due to be energized in September, 2009) For this substation, there will be two (2) independent SAS installations, which one SAS installation covering the 380 kV side of the substation (which will eventually be operated and maintained by SEC), and the second SAS installation covering the 115/13.8 kV sides of the substation (which will be operated and maintained by Ma’aden). It is noted that considerable interfacing and demarcation has been performed between Ma’aden and SEC as it pertains to ties between the 115 kV SAS and the 380 kV SAS to insure that the two SAS installations do remain under separate operations and maintenance responsibility.

- South Steel Plant in Jizan Economic City (2009 project-funded by the customer-due to be energized in late 2010) For this substation, there is one (1) SAS installation which will cover all voltage levels (380 kV, 132 kV and 13.8 kV levels), and SEC will eventually operate and maintain this SAS installation, after a two year SAS operations and maintenance agreement (immediately in effect after the energization of the substation) is completed by the Contractor.

As part of this initial rollout of SAS for these two 380 kV substations, a solid history will be obtained as it pertains to planning/engineering, operations/maintenance and other aspects of SAS for 380 kV substations to be considered for future 380 kV projects which may contain SAS. But for now, SAS will be stressed for lower voltage substations (132 kV and below).

Extension of rollout to lower voltage substations

For the 2009-2010 budget year, the stress for the rollout of SAS will be for lower voltage substations (132 kV and below). SEC Management has decided that for new 132 kV and below substations, that IEC 61850 based SAS will be the only control, data acquisition, and protection systems which will be considered. This rollout for SAS for the lower voltage substations, combined with the experience-
gained by SEC on the two (2) 380 kV SAS installations will provide SEC with a solid knowledge base for future SAS installations at all voltage levels for the 2011 and later SEC Budget years.

**Modification and amendment of existing SEC standards**

Currently, SEC has a very extensive standards database for substations which covers SEC Transmission Engineering Standards (TES), SEC Transmission Materials Standards Specifications (TMSS), and SEC Transmission Construction Specifications (TCS). However, many of these current SEC Standards have been developed based on “stand alone” systems (e.g. SCADA RTU’s, SOE RTU’s, etc.), and in their current form, cannot be adapted to SAS based installations without extensive modification and amendment. For example, current SEC Interlocking standards specify “hard-wired” interlocks only, and given that SAS does also contain both hard-wired and software/GOOSE interlocks, this standard has to be extensively modified and amended. For the modification/amendment activity, this will primarily be the activity of SEC Transmission Standards and Specifications Department who will consult with the SEC SAS Team.

**Development of new SEC standards related to SAS**

Given that some components related to SAS are not clearly identified in current SEC standards which are Engineering Standards, Materials Standards Specifications, and Construction Standards (for example, **IEC 61850** based Ethernet schemes for the **Inter-bay communications bus**), new SEC standards will need to be developed which will be specifically tailored to SAS components/systems using **IEC 61850**. It is expected that this new SEC Standards activity will take approximately 1 to 2 years to develop, and until these new SEC standards are developed and finalized, SEC will need to only consider SAS supply vendors with proven experience and background on a considerable number of past SAS equipped substations. Again, as with the modification and amendment of existing SEC standards, this will primarily be the activity of SEC Transmission Standards and Specifications Department who will consult with the SEC SAS Team.

**Development of SEC approved SAS equipment list**

As part of the overall SEC plans for transition to SAS, SEC will pursue activities related to developing an SEC approved SAS equipment and SAS Systems list. It is noted that, similar to development of new SEC standards related to SAS, this activity will probably take one to two years (with a mid-2011 completion) and until this new SEC approved SAS equipment list is developed and finalized, SEC will need to only consider SAS supply vendors with proven experience and background in supply of SAS equipment, and SAS systems for a considerable number of past SAS equipped substations. Again, this will primarily be the activity of SEC Transmission Standards and Specifications Department who will consult with the SEC SAS Team.

**Development of an SEC approved list of prequalified SAS Contractors and Subcontractors**

Given that with regard to SEC experience with SAS, and general Substation Construction contractors, many of the general Substation Construction Contractors do not have the detailed technical expertise in the installation and integration of SAS installations into their substations, and that many of the SAS equipment vendors/manufacturers/systems integrators do themselves build substations, but these vendors represent a limited bid list (limiting competition for bidding on overall substations which incorporate SAS, SEC decided to take the approach to develop an SEC approved list of prequalified SAS Contractors and Subcontractors. For SAS Contractors and SAS Subcontractors, this SAS Contractor/Subcontractor will be fully responsible for the overall engineering, supply, installation, testing/commissioning of SAS equipment/systems on a full turnkey basis under the direction and coordination with the main Substation Contractor. By using this approach, more open bidding for substations equipped with SAS can be accomplished, resulting in more competitive pricing for SEC and/or its customers. Again, in developing this SEC approved list of prequalified SAS Contractors and Subcontractors, this will take one to two years to finalize (with expected completion by mid-2011). During the interim period from 2009 to 2011, SEC will only be considering SAS Contractors/Subcontractors with proven contracting/subcontracting experience related to SAS installations at numerous SAS equipped substations worldwide, with an emphasis of this experience being for Electric Utilities in the GCC Region. Again, this development activity will primarily be the activity of SEC Transmission Standards and Specifications.
11. CONCLUSIONS

Saudi Electricity Company is continuously faced with the challenge to provide its customers with safe, affordable and reliable electricity. The need to monitor and control the substations and take accurate and timely precautions has become of paramount importance. The International Electro-technical Commission through its TC57 technical committee developed and released IEC61850 that swiftly responds to real time events with appropriate actions and has emerged to ensure the maintenance of uninterrupted power services to the end-users. Though there are still some draft standards in IEC61850 suites, there already have been several operators-accepted implementations to date. Acceptance of IEC61850 as the Substation Automation standard by SEC management has been timely, the IEC61850 version2 standard is also expected to be finalized by the end of year 2009. SEC by this time expects to have successfully implemented their first IEC61850 based Substation Automation System at Maaden 380/115KV Substation. The implementation process of Maaden 380/115KV SAS has been an enormous learning process and a great experience not only for the SAST members but for whole of the company. One aspect of this whole process is the ongoing revision of all the existing Transmission Engineering, Construction, Materials and other related Company standards to match the IEC61850 requirements and the other important aspect is the in-house development of one unified SAS standard for Company wide use. Another important aspect of introducing IEC61850 based SAS in the Company is the opportunity to look into the various disciplines within the Company related to Engineering, Operations, Maintenance, Testing & Commissioning and Project Management activities for Substation projects and reorganize the responsibilities and boundaries to adapt to the changing requirements. The roadmap for SAS in SEC is clear and SEC intends to benefit from the future developments on IEC61850 to meet the Company’s mission of providing its customers with safe and reliable electricity and at the same time meeting the expectations of the management and its shareholders.

12. REFERENCES

[1] B.Kruimer
Substation Automation – Historical Overview,
IEC Seminar, Kema, Amsterdam, August 2003

[2] Ivan De Mesmaeker1, Peter Rietmann, Klaus-Peter Brand, Petra Reinhardt ABB Switzerland Ltd. (Switzerland)
Substation Automation based on IEC 61850

PROTECTION AND SUBSTATION AUTOMATION SYSTEMS: STANDARDIZATION, INTEGRATION AND INFORMATION TECHNOLOGY

[4] Julian Alzate and Dave Dolezilek
Case Study: Design and Implementation of IEC 61850 From Multiple Vendors at CFE La Venta II

[5] Dave Dolezilek
IEC 61850: WHAT YOU NEED TO KNOW ABOUT FUNCTIONALITY AND PRACTICAL IMPLEMENTATION

IEC 61850 SCL - MORE THAN INTEROPERABLE DATA EXCHANGE BETWEEN ENGINEERING TOOLS

[7] Karlheinz Schwarz
IMPACT OF IEC 61850 ON SYSTEM ENGINEERING, TOOLS, PEOPLE-WARE, AND THE ROLE OF THE SYSTEM INTEGRATOR

SUBSTATION COMPONENTS PLUG AND PLAY INSTEAD OF PLUG AND PRAY The impact of IEC 61850

[9] Mark Adamiak, Ron Patterson, Jerry Melcher
Inter and Intra Substation Communications: Requirements and Solutions

[10] Karlheinz Schwarz
Information models and information exchange for electric power systems