SCADA/Business Network Separation: Securing an Integrated SCADA System

This white paper is based on a utility example but applies to any SCADA installation from power generation and distribution to water/wastewater management and control. Although the SCADA installations may vary in their function, securing them is very similar, whether used in a utility or a manufacturing facility.

In recent years, utility companies have undergone great changes in the way they run their businesses. The pressure to increase profits and reduce expenses has them integrating their SCADA systems with their business networks to streamline operations. The popularity of the Internet has customers requesting online access to their accounts as well as online bill payment, further increasing network exposure. In addition, utility companies have reduced costs by leveraging the Internet to facilitate core business operations such as outage management and procurement.

The August 2003 mass power outage heightened public concern about the possibility of an intentional outage. As a result North American Electric Reliability Council (NERC) created the Urgent Action Standard 1200. The purpose of this action was to ensure all entities responsible for the reliability of the bulk electric systems in North America identify and protect critical cyber assets that control or could impact the reliability of bulk electric systems. In 2004, NERC issued a continuation and update of Standard 1200 that remains mandatory for control areas and reliability coordinators. All control areas and reliability coordinators must complete and submit the appropriate regional self-certification renewal form(s) indicating their degree of compliance or non-compliance with the cyber security standard requirements during the first quarter of 2005.

In addition, global terrorism has the public and media concerned about the security of public utility companies’ critical infrastructure and their SCADA systems. Despite the public fears, there is no reason for utility companies to shun the immense benefits resulting from the integration of SCADA systems and the advantages of the Internet. The threat may be real, but the measures to protect SCADA systems are, fortunately, relatively easy.

Perhaps the greatest danger to utility companies is the lack of awareness of the need for greater security. Many public and private companies controlling vital public utilities like gas, power and water, never thought they would be the target of cyber attacks and now must implement measures to improve network security. While many utility companies perform regular risk assessments of their SCADA systems, too many do not. They have become dependent on their tightly integrated digital information systems without fully understanding the potential impact of a cyber attack.
SCADA systems were traditionally “walled off” from other systems operating independently from the network. Prior to the awareness of possible attacks, this seemed to provide all the protection the SCADA system needed. They were largely proprietary systems with such limited access and esoteric coding that very few people would have the ability to access them to launch an attack. Over time, however, they became integrated into the larger company network as a means to leverage their valuable data and increase plant efficiency. Therefore, the reality is their security is now often only as strong as the security of the network.

Protecting Your SCADA Network

The first step
The first step towards securing SCADA systems is creating a written security policy, an essential component in protecting the corporate network. Failure to have a policy in place exposes the company to attacks, revenue loss and legal action. A security policy should also be a living document, not a static policy created once and shelved. The management team needs to draw very clear and understandable objectives, goals, rules and formal procedures to define the overall position and architecture of the plan.

Key personnel such as senior management, IT department, human resources and the legal department all should be included in the plan. It should also cover the following key components:
- Roles and responsibilities of those affected by the policy
- Actions, activities and processes that are allowed and those that are not allowed
- Consequences of non-compliance

Vulnerability Assessment
A key aspect of preparing a written security policy is to perform a vulnerability assessment prior to completing the written policy. A vulnerability assessment is designed to identify both the potential risks associated with the different aspects of the SCADA-related IT infrastructure and the priority of the different aspects of the infrastructure. This would typically be presented in a hierarchical manner, which in turn sets the priority to address security concerns and the level of related funding associated with each area of vulnerability.

For example, within a typical SCADA environment, key items and the related hierarchy could be as follows:
- Operational Availability of Operator Stations
- Accuracy of Real Time Data
- Protection of System Configuration Data
- Interconnection to Business Networks
A vulnerability assessment also acts as a mechanism to identify holes or flaws in the understanding of how a system is architected and where threats against the system may originate.

To successfully complete a vulnerability assessment, a physical audit of all the computer and networking equipment, associated software and network routings needs to be performed. A clear and accurate network diagram should be used to present a detailed depiction of the infrastructure following the audit.

After defining the hierarchy and auditing the different system components, the following areas of vulnerability need to be addressed, as they relate to each component, as part of the assessment process:

Network and operating environment security

- Application security
- Intrusion detection
- Regulation of physical access to the SCADA network

It should also be understood when dealing with the SCADA infrastructure that there are commonalities and differences between SCADA-related IT security and IT security focused on typical business systems. For example, in a business systems environment, access to the server is typically the key focus. Whereas in a SCADA environment, the access focus is at the operator console level. This difference produces both alternate network topologies to provide the necessary availability as well as a different focus on what elements of the SCADA system would be of highest priority to safeguard against security breaches.

Further Security Measures

As previously mentioned, SCADA networks were once separate from other networks and physical penetration of the system was needed to perpetuate an attack. As corporate networks became electronically linked via the Internet or wireless technology, physical access was no longer necessary for a cyber attack. One solution is to isolate the SCADA network; however, this is not a practical solution for budget-minded operations that require monitoring plants and remote terminal units (RTU) from distant locations. Therefore, security measures need to be taken to protect the network, and some common security mechanisms apply to virtually all SCADA networks, which have any form of wide area (WAN) or Internet-based access requirements. The core elements of each method are discussed in the following:

Network Design – Keep It Simple
Simple networks are at less risk than more complex, interconnected networks. Keep the network simple and, more importantly, well documented from the beginning.

A key factor in ensuring a secure network is the number of contact points. These should be limited as far as possible. While firewalls have secured access from the Internet, many existing control system have modems installed to allow remote users access to the system for debugging. These modems are often connected directly to controllers in the substations. The access point, if required, should be through a single point that is password protected and where user action logging can be achieved.

**Firewalls**

A firewall is a set of related programs, located at a network gateway server that protects the resources of a private network from outside users. A firewall, working closely with a router program, examines each network packet to determine whether to forward it toward its destination. A firewall also includes or works with a proxy server that makes network requests on behalf of workstation users. A firewall is often installed in a specially designated computer separate from the rest of the network, so that no incoming request can get directly at private network resources.

In packet switched networks such as the Internet, a router is a device or, in some cases, software in a computer, that determines the next network point to which a packet should be forwarded toward its destination. The router is connected to at least two networks and decides which way to send each information packet based on its current understanding of the state of the networks to which it is connected. A router is located at any gateway (where one network meets another), including each point of presence on the Internet. A router is often included as part of a network switch.

It is imperative to utilize a secured firewall between the corporate network and the Internet. As the single point of traffic into and out of a corporate network, a firewall can be effectively monitored and secured. It is important to have at least one firewall and router separating the network from external networks not in the company’s dominion.

On larger sites the control system needs to be protected from attack within the SCADA network. Implementing an additional firewall between the corporate and SCADA network can achieve this aim and is highly recommended.
Firewall Design for a SCADA Network
Virtual Private Network (VPN)

One of the main security issues facing more complex networks today is remote access. VPN is a secured way of connecting to remote SCADA networks. With a Virtual Private Network (VPN), all data paths are secret to a certain extent, yet open to a limited group of persons, such as employees of a supplier company. A VPN is a network constructed by using public wires to connect nodes. For example, there are a number of systems that allow the creation of networks using the Internet as the medium for transporting data. These systems use encryption and other security measures to ensure only authorized users access the network and data cannot be intercepted. Based on the existing public network infrastructure and incorporating data encryption and tunneling techniques, it provides a high level of data security. Typically a VPN server will be installed either as part of the firewall or as a separate machine to which external users will authenticate before gaining access to the SCADA networks.

IP Security (IPsec)

IP Security (IPsec) is a set of protocols developed by the Internet Engineering Task Force (IETF) to support the secure exchange of packets at the IP layer. IPsec has been deployed widely to implement VPNs.

IPsec can be deployed within a network to provide computer-level authentication, as well as data encryption. IPsec can be used to create a VPN connection between the two remote networks using the highly secured Layer Two Tunneling Protocol with Internet Protocol security (L2TP/IPSec).

IPsec supports two encryption modes: Transport and Tunnel. The Transport mode encrypts only the data portion (payload) of each packet, but leaves the header untouched. The more secure Tunnel mode encrypts both the header and the payload. On the receiving side, an IPsec-compliant device decrypts each packet.

For IPsec to work, the sending and receiving devices must share a public key. This is accomplished through a protocol known as Internet Security Association and Key Management Protocol/Oakley (ISAKMP/Oakley), which allows the receiver to obtain a public key and authenticate the sender using digital certificates.

It is important during the selection process of network hardware such as routers, switches and gateways to consider the inclusion of support for IPsec security as part of the devices to enable the support of secure VPN connections.

Demilitarized Zones (DMZ)

Demilitarized Zones (DMZ) are a buffer between a trusted network (SCADA network) and the corporate network or Internet, separated through additional firewalls and routers, which provide an extra layer of security against cyber attacks. Utilizing DMZ buffers is becoming an increasingly common method to segregate business applications from the SCADA network and is a highly recommended additional security measure.
Demilitarized Zones (DMZ)
Application Security

In addition to securing the network, securing access to SCADA system components will provide a further defense layer.

**Authentication** is the software process of identifying a user who is authorized to access the SCADA system. **Authorization** is the process of defining access permissions on the SCADA system and allowing users with permissions to access respective areas of the system. Authentication and authorization are the mechanisms for single point of control for identifying and allowing only authorized users to access the SCADA system, therefore ensuring a high level of control over the system’s security.

To provide effective authentication the system must require each user to enter a unique user name and password. A shared user name implies a lack of responsibility for the protection of the password and any actions completed by that user.

It must be possible for user names to be created, edited and deleted within the system while the system is active to ensure individual passwords can be maintained. In addition it is highly recommended that password aging be implemented. Password aging ensures that operators change their passwords over a controlled time period, such as every week, month, or so on.

To provide authorization the system must be able to control access to every component of the control system. The system must not provide a “back door” by which to bypass the levels of authentication specified in the application.

Critical data pertaining to a SCADA system must be securely stored and communicated. It is essential that critical data like a password be stored using an encryption algorithm. Similarly, remote login processes should use VPNs or encryption to communicate the user name and password over the network.

Critical data like user name and password must be persisted in a secured data repository and access rights monitored and managed using secured mechanisms like Windows authentication and role-based security. It has become common practice for SCADA systems operating in the Windows environment to utilize Windows Domain security to maintain user profiles. This is a recommended approach as it centralizes security and administration while providing an acceptable audit trail of user actions.
Audit Trails

It is recommended that Audit trails on critical activities like user logins, changes to operational parameters or changes to system access permissions be tracked and monitored at regular intervals. Securing your SCADA application may make it more challenging for external hackers to gain control of the system; however it will not prevent internal sabotage. Regularly tracking and monitoring audit trails on critical areas of your SCADA system will help identify suspicious activities and consequently allow the necessary corrective actions.

Wireless Networks

The two most common ways of gaining unauthorized access to a wireless network are by using an unauthorized wireless client, such as a laptop or PDA, or by creating a clone of a wireless access point. If no measures have been taken to secure the wireless network then either of these methods can provide full access to the wireless network.

Many commercial wireless networks are available, which range in price, complexity and level of security provided. When implementing a wireless network, a couple of standard security measures can minimize the chance of an attacker gaining access to the wireless network.

- **Approved clients** – The access points in the wireless network contain a configurable list of all MAC addresses of the authorized clients that are permitted access to the wireless network. A client not listed in an access point cannot access the wireless network.

- **Server Set ID (SSID)** – This is an identification string that can be configured on all clients and access points in your wireless network. Any client or access point participating on the wireless network must have the same SSID configured. The SSID is, however, transmitted as a readable text string over the network. Therefore, an SSID alone is not sufficient to secure the wireless network.

- **Wired Equivalent Privacy (WEP)** – All clients and access points should have a configurable static WEP. This is a 40, 64 or 128-bit encryption string that is entered in all clients and access points. Without a correct WEP string, no access can be gained to the wireless network. The SSID is also encrypted using this string. In most cases, using an SSID and a WEP provides a secure solution.

- **802.1X EAP (Extensible Authentication Protocol)** – WEP is the minimum level of security recommended for wireless client access. The disadvantage with WEP is the management of the network strings. It is possible to decode these, and updating to new keys is a manual process. EAP is a relatively new standard that dynamically alters keys while providing built-in authentication requirements. It is recommended where possible EAP authentication is enabled for wireless devices.

- **VPN** (described earlier) was developed to provide secure connections through the Internet to internal corporate networks. A VPN simplistically creates a secure tunnel through open networks such as the Internet or a wireless network. Data transmitted through the tunnel is encrypted on the client then decrypted and validated in a VPN gateway inside the wireless access point. VPN is a single solution providing security both for the wireless and wired network, thus reducing implementation and maintenance costs.
Intrusion Detection

Firewalls and other simple boundary devices currently available lack some degree of intelligence when it comes to observing, recognizing and identifying attack signatures that may be present in the traffic they monitor and the log files they collect. This deficiency explains why intrusion detection systems (IDS) are becoming increasingly important in helping to maintain network security.

In a nutshell, an IDS is a specialized tool that reads and interprets the contents of log files from routers, firewalls, servers and other network devices. Furthermore, an IDS often stores a database of known attack signatures to compare patterns of activity, traffic or behavior it identifies in the logs it monitors against those signatures. There are various types of IDS monitoring approaches:

- **Network-based IDS characteristics** – A network-based IDS monitors an entire, large network with only a few well-situated nodes or devices and impose little overhead on a network.

- **Host-based IDS characteristics** – A host-based IDS analyzes activities on the host it monitors at a high level of detail. It can often determine which processes and/or users are involved in suspicious activities.

- **Application-based IDS characteristics** – An application-based IDS concentrates on events occurring within a specific application. They often detect attacks through the analysis of application log files and can usually identify many types of attack or suspicious activities.

In practice, most utilities use a combination of network, host and/or application-based IDS systems for observing network activity while also monitoring key hosts and applications more closely.

Redundant Control Centers

For both physical disaster recovery and IT intrusion and isolation purposes most utility companies are now adopting SCADA solutions that incorporate at least one off site control center. In some utility sectors this is now mandatory. This should be seriously considered as part of the overall security assessment of the IT infrastructure. For a redundant off-site center to operate effectively the following items need to be considered as part of the infrastructure requirements:

- Automatic failover of all controller-based communications

- Full historical data replication between each of the servers deployed within the system.
Redundant Control Centers
Additional Resources

This discussion is intended as an overview of the security measures to protect an integrated SCADA network. In no way is it fully comprehensive or intended as the sole source for network security. Listed below are some agencies that publish current standards and security measures that can aid you in your security planning.

*The Instrumentation, Systems and Automation Society (ISA)*
www.isa.org

*National Institute of Standards and Technology (NIST)*
www.csrc.nist.gov

*North American Electric Reliability Council (NERC)*
www.nerc.com

*United States Department of Energy (DOE)*
www.energy.gov

*U.S. Department of Homeland Security*
www.nipc.gov

*Sandia National Laboratories – The Center for SCADA Security*
www.sandia.gov/scada/home.htm

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