

## Secure Plant Infrastructure through Remote Substation Monitoring

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### ABSTRACT

Ensuring the security of a utility's remote physical assets, such as electric substations, through a Web-based camera monitoring system yields benefits both in terms of security and operational efficiency. Users can control the cameras to capture either video, thermographic, or still images using a custom Web interface or be automatically alerted to events occurring at their remote asset's location. This solution provides powerful value in predictive maintenance, remote visual inspections, and site security.

This paper describes how remote access technology can be applied and the actual implementation of a remote monitoring system. It explains the capabilities of remote monitoring and control technology, including options for camera set-up and functions such as panning and zooming, visual and thermographic imaging, alarming and autonomous control. It also describes the benefits of remote monitoring, including improved safety and security, avoidance of false alarms, gathering of supervisory control and data acquisition (SCADA) information, being alerted to operational situations requiring repair or preventative maintenance, and more efficient dispatch of personnel. A case study and demonstration will be presented.

**Keywords:** Remote facility monitoring, web-based, thermographic cameras, predictive maintenance

### INTRODUCTION

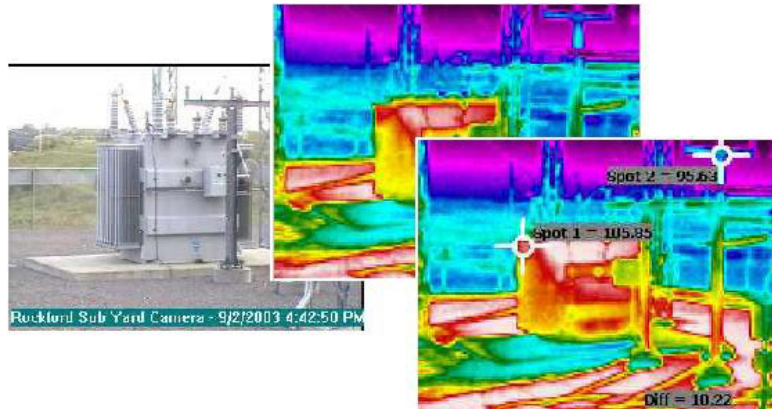
The importance and attention given to asset security has reached unprecedented highs in recent years as organizations try to protect their remote fixed assets. These assets include electrical substations, telecommunication hub sites, water treatment facilities, well-heads and dispersed manufacturing plants. Protecting assets involves more than simply deterring vandalism or investigating an incident. Maintenance, dispatch and operational issues are also involved in providing a complete asset protection package. Typical security systems do not address these operational aspects.

### MULTIPLEXING BENEFITS

MiniMax's ScadaCam system, coupled with FLIR thermographic technology, provides not only security and monitoring, but also the critical link between remote site security, system control, data acquisition and visual event confirmation. Multiplexing these functions provides significant benefits over deploying stand alone systems. It is much easier to justify a remote security and monitoring system if it can interface with existing systems and couple with optical and/or thermographic cameras, enabling remote users to view the smallest level of detail at a site while autonomously monitoring facilities for activity.



Figure 1. Equipment details captured by camera for measurement readings



**Figure 2.** Thermographic views and the ability to display spot temperatures as shown in the images above can be an important operational benefit, especially for critical infrastructure.

### TRADITIONAL SECURITY SYSTEMS

For many years corporate video surveillance and monitoring typically involved closed circuit television (CCTV) systems that required either active event monitoring from a central area or utilized VCRs or digital video recorders (DVRs) on site to record events. CCTV presented two major disadvantages: by definition it is a closed communications system and it is intended for limited viewing in one monitoring location. If CCTV remote monitoring is deployed, it typically requires a substantial investment in equipment, cabling, computer software and entails complex installation procedures. Remote monitoring involves a point-to-point link over a costly network, large bandwidth requirements and provides moderate performance at best. The passive nature of this type of monitoring limited its effectiveness.

Compare traditional CCTV tools to solutions that compress security video information into a digitized data stream that is transmitted via an existing corporate network. The information can be viewed in real time by multiple authorized users through Web browsers. Events at the location can proactively trigger notification alerts to those monitoring the site. These can be SCADA system status, motion detection, sensor detection, or the FLIR Systems' A20 camera capability to generate an alarm in response to temperature changes. Integrating surveillance video enhances employee safety, controls access points and minimizes loss of corporate assets. Enabling response to emergency situations is a compelling reason to supplement current surveillance systems with network attached image capabilities. Every year companies respond to 15 million false alarms – a costly activity that could be reduced by availability of live images transmitted inexpensively via networks. Allowing images to be sent, stored, and recalled via the Internet enables security personnel to study surveillance circumstances from any location.



**Figure 3.** Liquid level gauge viewed from approximately 300 feet.

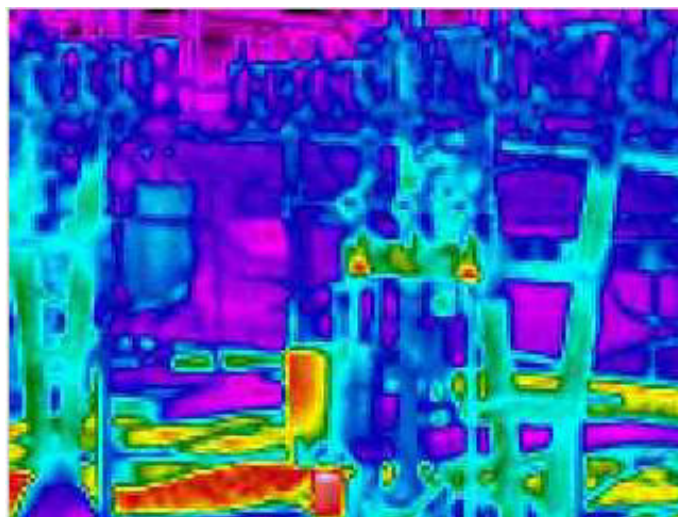
## MAINTENANCE AND OPERATIONS FUNCTIONS

Traditional SCADA systems monitor system status and return data to system operators and dispatchers. Typically they do not perform maintenance inspection functions and often are not utilized fully due to the cost of deploying transducers or IEDs and building the appropriate interfaces and data repositories. A security and monitoring system can augment an existing SCADA system by providing access to non-traditional SCADA data. For example, Figure 3 shows a liquid level gauge shot from about 300 feet away. The cost to install and configure a dedicated SCADA point was cost-prohibitive, so this utility configured a pre-set that zooms in and captures the gauge position. This view can be checked when necessary or a periodic scan can be configured to e-mail the image of the gauge to the proper personnel.



*Figure 2. The oil level is clearly apparent in this 69,000 volt transformer bushing.*

A security and monitoring system also should be capable of performing routine maintenance operations. Figure 4 shows a 69,000 volt transformer bushing that is filled with insulating oil, making the placement of sensors prohibitive. If the oil leaks out there can be a catastrophic transformer failure. Configuring ScadaCam to perform periodic maintenance scans provides a mechanism to check on equipment conditions in remote areas on a much more regular basis than possible by on-site inspections.



*Figure 3. Thermographic image shows temperature rise in the bushings of a feeder breaker*

Occasionally, operational failures occur in the field that can not be predicted or seen by the naked eye. Deploying a dedicated FLIR thermographic camera at critical facilities can potentially reduce the chance of a catastrophic failure. Take, for example, a bulk transformer at a power generation plant. If the transformer fails due to a loose connection it may not only cause several million dollars worth of equipment damage, but can also take the plant out of operation for weeks or months resulting in hundreds of millions of dollars in lost production. Monitoring critical facilities such as this can easily pay tremendous returns. Figure 5 clearly shows the temperature rise in the two outside bushings of a feeder breaker.

### **Ubiquitous Access**

The ability to provide access to users from any Internet-connected PC is not only convenient but critical for many organizations. On-call personnel that are alerted to a problem can check on-line the extent and severity of a situation before responding. This can lead to faster problem resolution and avoiding nuisance alarms. Field technicians can get remote assistance from off-site personnel by directing them to the camera and visually showing the problem remotely.



*Figure 4. Visual confirmation of closed switch position.*

### **Safety Considerations**

Dispatch personnel can visually verify remote device operations, enhancing personnel safety. As shown in Figure 6, a dispatcher, after initiating a 69kV switching operation, can visually verify the switch's closed position. This provides switch status validation and can also be used to confirm the switch is seated properly. Ensuring the device operated properly gives office and field personnel confidence that there were no mechanical failures during the operating event. See Figure 6.

### **AUTONOMOUS OPERATION**

A monitoring and security system's ability to operate autonomously is imperative, not only from a cost justification standpoint but also functionally. Attempting to visually monitor multiple cameras at multiple sites quickly escalates from difficult to impossible. For this reason it is important to autonomously alert users – security, dispatch, engineers, technicians, maintenance – when events occur, rather than passively recording events or waiting for human direction. These alerts, alarms and reports can be segmented and directed to targeted personnel. Security can receive transgression alerts; system operators can be fed switch status images on switch position changes; maintenance technicians can receive daily equipment checks. A series of examples illustrates this concept:

#### **Example #1: Motion in north parking lot**

A proximity detector, set to scan a parking lot, picks up motion. The camera system goes into action,

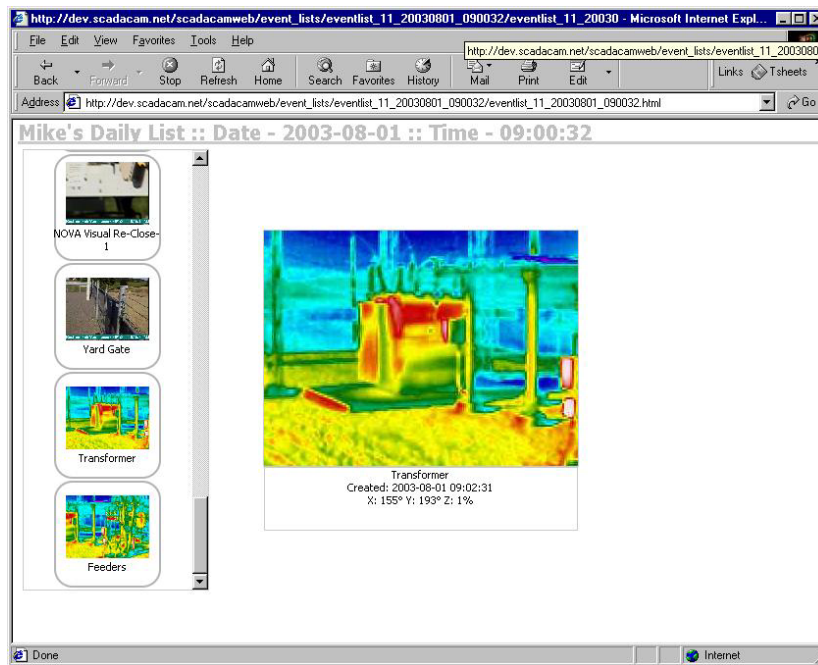
recording an antifreeze spill from the grader onto the gravel parking lot. This video, in addition to being recorded as an event, can be automatically sent to security for immediate action. See Figure 7.



**Figure 5.** Video record taken by a camera programmed to respond to a proximity alarm.

### Example #2: Maintenance scan

A pre-programmed maintenance scan – set to operate once a day at 9:00 in the morning – e-mails a video maintenance report to a substation supervisor. The supervisor can click on any one of the images on the left side of the e-mail and see an enlarged picture. This enables him to initiate maintenance actions immediately, if required, rather than waiting for a failure or having to drive to the site to perform a visual inspection. See Figure 8.



**Figure 6.** Example of a pre-programmed infrared maintenance scan automatically e-mailed to a supervisor.

### Example #3: SCADA alarm verification

A SCADA alarm sounds at dispatch, indicating a low voltage condition in a substation. The camera instantly pans to and focuses on that location and begins capturing the event. An e-mail and a pager text message is automatically sent to dispatch by the system, showing the status of the high side fuses protecting the substation. Intact fuses indicate the problem is upline. Personnel can then further manipulate the cameras in real time to better understand the situation.



*Figure 7. Intact high-side fuse indicates the cause of a low-voltage problem lies upline.*

#### **Example #4: Equipment Operation**

A substation feeder breaker begins to operate, tripping power on and off as it automatically attempts to clear a fault (short circuit). This is typically a routine event because the source of the fault is downstream from the substation. Occasionally, however, the fault occurs in the substation. An automated system can respond to a breaker operation, record the tripping sequence and send the video of the event to the system dispatcher. Dispatch can review the event recording and determine the appropriate action – without sending someone to the site first to see what caused the problem. This significantly speeds up restoration of service.

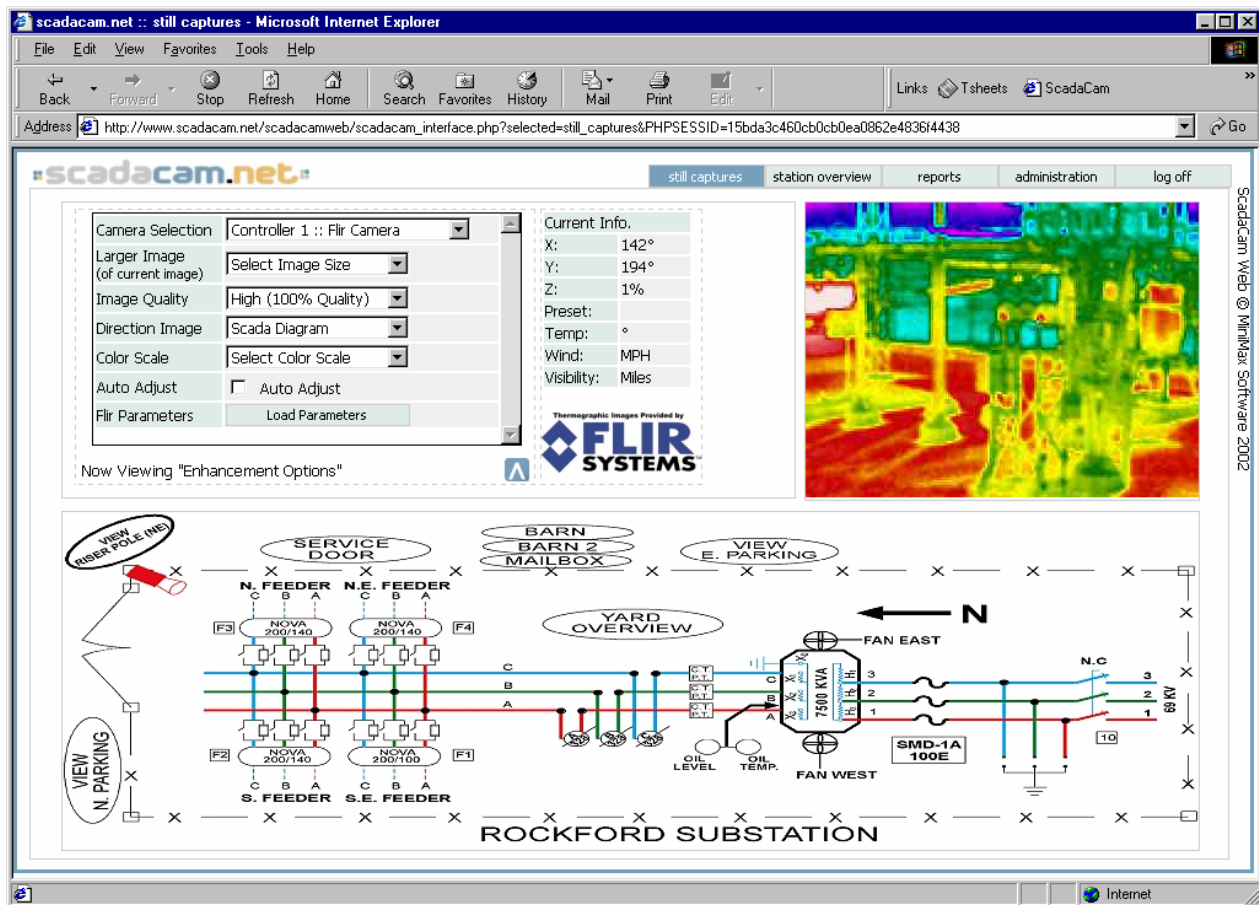
### **REMOTE ASSET PROTECTION SOLUTION**

#### **The ScadaCam Solution**

ScadaCam is an IP-based, pan-tilt-zoom, digital camera system that can be viewed and controlled remotely through a Web browser. The system is composed of a camera wired to an On-site Data Controller (SODC). The SODC processes requests from remote Web browsers, controls camera movement, digitally stores images, video and data, runs pre-programmed scan routines, accepts external inputs, and handles all of the systems TCP/IP communications.

The system also has the unique ability to quickly and reliably move to a predefined location and capture data without human input. This is accomplished using a 360 degree precision camera control system. With 1,600 discrete steps in X, Y, and Z planes, the system can capture overlapping video frames at 2,500 feet (762 m). In more practical terms this means the camera picture will move only 7 inches (18 cm) between “stops” when looking at an object 150 feet (46 m) away.

The system employs a sophisticated control scheme that enables the camera to return to any preset location repeatedly. This means that without user input or guidance, the camera moves and zooms to the exact position of an item of interest. Movement can be tied into external inputs such as proximity detectors, recloser control outputs and SCADA contacts. These inputs act as triggers directing the system to perform pre-defined operations such as capturing still recording, fixed position video, or recording streaming video while the camera is panning and zooming. These features can be used for periodic substation inspections, alerting dispatch of any security breaches and recording switch, breaker or recloser operations while they are occurring. All these actions can be programmed to alert dispatch or other utility personnel when a specific event occurs, rather than by the traditional closed-circuit security system method of showing video streams on a bank of monitors that must be monitored for activity.



*Figure 8. The ScadaCam Web browser graphical user interface.*

### Operational Characteristics

Ease of use is imperative if a security and monitoring system is to be used throughout an organization. It should be able to operate as both an automatic and an interactive tool. Users, using any Web browser must be able to interact and direct camera operations. A user-friendly graphical user interface (GUI) is mandatory. The following images provide an operational overview:

**Point and Click Direct Camera Control.** Clicking anywhere in an image pane directs the camera to move and capture a new image. The new view is centered on the clicked area.

**Point and Click Schematic Diagram.** A hot-linked schematic diagram enables users to select specific equipment, gauges or substation features to view quickly and easily. Clicking on any schematic element directs the camera to move and capture an image of the desired area.

The HMI components described here are part of the system's basic functionality. Specifically:

- **Image Window:** The image window contains the image returned by the remote and controller.
- **Zoom Bar:** The zoom bar lets the user visually control the camera zoom scale. Moving the zoom bar up and down then clicking on the picture will redirect the camera to zoom in (or out) and snap a new image.
- **Schematic View:** The Schematic view is a representation of the facility. Relevant schematic elements are hot-linked, to specific camera views.

## Environmental Considerations

Operating in harsh, remote environments will take a toll on any field equipment. Minimizing the effects of extreme heat and cold is imperative. Providing a thermally controlled, industrial quality enclosure is very important. Using Peltier devices, ScadaCam can heat or cool the camera enclosure up to 30° F from ambient. Additionally, the control motors can be safely overdriven to produce heat, enough to melt ice and snow accumulations in freezing temperatures.

## Reporting Functionality

Active functions, such as gathering information and alerting appropriate personnel, should be logged as activity reports for future retrieval. Figure 11 shows a record of motion detection in the substation yard, which triggered a video recording event. All activities are time and date stamped and are tagged with a description of the event trigger and the subsequent digital video capture.

The screenshot displays the ScadaCam web interface in a Microsoft Internet Explorer browser. The address bar shows the URL: [http://www.scadacam.net/scadacamweb/scadacam\\_interface.php?selected-reports&PHPSESSID=15bda3c460cb0cb0ea0862e4836f4438](http://www.scadacam.net/scadacamweb/scadacam_interface.php?selected-reports&PHPSESSID=15bda3c460cb0cb0ea0862e4836f4438). The interface features a navigation menu with options: still captures, station overview, reports, administration, and log off. A sidebar on the left shows a tree view of site activities, with the following entries:

- Expand Collapse
- Site Activity @ 08/30/2003 02:37:47 PM
- Site Activity @ 08/30/2003 03:52:40 PM
- MotionDetector:Motion Sub Station Y...
- Site Activity @ 08/30/2003 08:06:59 PM
- Site Activity @ 08/31/2003 08:02:28 AM
- Site Activity @ 08/31/2003 09:19:06 AM
- Site Activity @ 08/31/2003 10:02:09 AM
- Site Activity @ 08/31/2003 02:34:46 PM
- Site Activity @ 08/31/2003 04:07:52 PM
- Site Activity @ 08/31/2003 04:58:36 PM
- Site Activity @ 08/31/2003 06:47:54 PM
- Site Activity @ 09/01/2003 08:20:23 AM
- Site Activity @ 09/01/2003 08:57:07 AM
- Site Activity @ 09/01/2003 09:59:26 AM
- Site Activity @ 09/01/2003 02:07:16 PM
- Site Activity @ 09/01/2003 03:17:30 PM
- Site Activity @ 09/01/2003 03:36:12 PM
- Site Activity @ 09/01/2003 04:21:25 PM
- Site Activity @ 09/01/2003 05:10:57 PM
- Site Activity @ 09/01/2003 05:47:56 PM
- Site Activity @ 09/01/2003 06:15:12 PM
- Site Activity @ 09/01/2003 07:15:33 PM
- Site Activity @ 09/02/2003 06:53:26 AM
- Site Activity @ 09/02/2003 01:56:18 PM
- Site Activity @ 09/02/2003 04:33:24 PM
- Site Activity @ 09/02/2003 04:51:47 PM
- Site Activity @ 09/02/2003 06:17:57 PM
- Site Activity @ 09/02/2003 07:08:41 PM
- Site Activity @ 09/03/2003 08:03:21 AM
- Site Activity @ 09/03/2003 10:02:49 AM
- Site Activity @ 09/03/2003 10:28:42 AM

The main content area displays a table titled "Site Activity @ 08/30/2003 03:52:40 PM" with columns for Time, Description, and Media. The table contains the following data:

Time	Description	Media
03:52:40 PM	MotionDetector:Motion Sub Station Yard - Triggered On	
03:52:41 PM	VideoCapture of Video_20030830_155240.avi has started to record	
03:52:47 PM	MotionDetector:Motion Sub Station Yard - Triggered OFF	
03:53:40 PM	VideoCapture of Video_20030830_155240.wmv finished recording	
03:54:21 PM	Uploaded File - Video_20030830_155240.wmv	

Below the table, a "ScadaCam Media Player" window is open, displaying a video feed from the "Rockford Sub Yard Camera" at 8/30/2003 3:52:49 PM. The video is paused at 00:04. The player includes controls for Fullscreen and Close.

*Figure 9. Report of motion detection event captured on video.*

Any operation can be logged as an event. If the site were divided into 10, 20, 30 or more security zones – including gate switches, door switches, fence trip wires, etc., the system could log activity in each zone.

## CONCLUSION

### Value Proposition Summary

Implementing an autonomous security and monitoring system provides several benefits:

- Unmanned monitoring through activity-alert driven inputs and outputs
- Self directed alerts, reports and alarms – delivery to the appropriate personnel
- Previewing alerts helps reduce responses to false alarms
- Scheduled daily inspections decrease the number of on-site visits
- Visualizing measurements over time can help determine operational characteristics

- Provides a proactive approach to monitoring remote facilities

Standard maintenance procedures, schedules and standards are harder to enforce with remote assets. In addition, the growing complexity of infrastructure, in many cases the increasing age of these assets, and the pressures for better productivity from the organization that supports them places maintenance in the center of operational priorities. Protecting and supporting these assets requires more than passive video surveillance. Solutions that incorporate a variety of detector inputs, varied visual inputs such as thermography, still cameras, and video, and allow for rapid remote manipulation that can be accessed from any Web browser are best positioned to be capable of responding and alerting to any activity as well as adopting to future innovations. While proactive security solutions add value, a comprehensive approach that incorporates maintenance and operational priorities creates a higher return on investment.

### **ACKNOWLEDGEMENT**

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