# Electric Substation Monitoring

Electric power utilities are faced with an aging infrastructure, increasing risk of blackouts and brownouts, costly unplanned maintenance, security threats to remote facilities, and rising costs. As part of a government/industry initiative, utilities are looking for ways to address these issues that will improve the reliability of electric power delivery while reducing costs. FLIR is participating in these efforts by working with various partners and utilities to improve the monitoring of electric substations. Through the use of FLIR's "smart" infrared cameras and automation software, impending equipment failures and security breaches can be detected anytime, day or night, at a remote monitoring location. The net effect is increased reliability and reduced cost.

EARLY WARNING OF SUBSTATION PROBLEMS

- Supports US Smart Grid Initiative
- Remote monitoring of critical substation components
- Helps increase reliability without adding personnel
- Ethernet and wireless connections to a central control room
- See intrusions with live images on TV, PC monitor, or PDA
- Obtain temperature readouts of overheating
- Spot nonfunctioning equipment with low temperatures
- Instantly trigger audible and visual alarms
- Notify management via email and intranet connections
- Works day or night in any weather – 24/7 operation
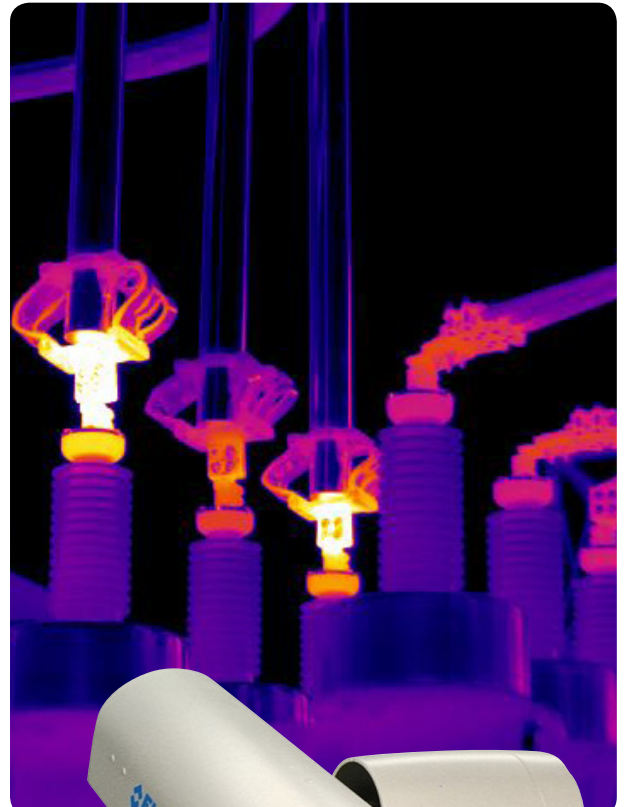
This publication is one of the FLIR Solution Series that describes important applications for IR camera systems. This Series is designed to show our customers how FLIR systems can be used to help reduce costs by protecting their assets, improving production automation and machine vision processes, and increasing the value of their predictive/preventative maintenance operations. The images, case histories, and system designs described in this Series are merely examples of the many possibilities available to users of FLIR IR cameras. Your feedback on the Series will be sincerely appreciated; you can respond by email to moreinfo@flir.com, by telephone to 800.464.6372, or by letter to FLIR Systems, Inc. 25 Esquire Rd. North Billerica, MA 01826.

Failure Cause and Effect

the risk of blackouts and brownouts are increasing on the US power distribution grid due to its aging infrastructure, and a lack of automation systems that monitor the condition of critical equipment at substations and elsewhere on the grid. For example, transformer fluid leaks or internal insulation breakdown cause overheating that leads to failures, but many utilities don't have automated thermal detection systems that reveal these problems. In addition, the remote locations of many substations make them vulnerable to security breaches, which can be detected with automated infrared imaging systems.

Whatever the cause, a critical substation failure may cascade into series of failures. Indeed, aging substation infrastructure exacerbated the Northeast blackout of 2003, the largest in US history. The result was a massive failure of regional banking facilities, security systems, manufacturing plants, food refrigeration, communication networks, and traffic control systems. Of course, the electric utilities involved lost huge amounts of revenue and incurred enormous costs in getting their systems up and running again. The economic impact is thought to have exceeded $6 billion in the region.

Smart Grid Initiative

To help modernize our electric power grid, the US Department of Energy (DOE) is establishing partnerships with public and private organizations that understand the need for new technology and operational methods. These organizations include the GridWise Alliance, National Institute of Standards and Technology (NIST), US Department of Commerce, American National Standards Institute (ANSI), Institute of Electrical and Electronics

Engineers (IEEE), and many others that share a common goal of increasing the reliability and cost effectiveness of our power grid. A principal objective is to enable a smarter, more secure grid by employing innovative technology and equipment across a wide range of applications and enterprises.

FLIR is working with its partners and electric utilities to apply infrared (IR) imaging technology to improve the reliability and security of electric substations. Although electric utilities have for many years used handheld IR cameras to monitor substation equipment, they are now turning to permanently installed camera systems. Through the use of automated IR cameras and innovative software, FLIR and its partners have developed monitoring systems that provide early warning of impending equipment failures and security breaches.

These systems employ advanced sensing and measurement technology, control methods, and digital communications that are becoming part of the Smart Grid system. They are able to anticipate, detect, and respond rapidly to problems, thereby reducing maintenance costs, the chance of failure, a blackout, and lost

productivity. For example, one large US utility discovered a hot bushing rod in a substation transformer and repaired it at a cost of only $16,000. A similar problem that occurred before the firm instituted its IR program resulted in a catastrophic failure that cost more than $3,000,000.

A few substation components whose thermal signatures are precursors to failure include:
- Power transformers (oil levels and pump operation)
- Load tap changers (oil levels, other internal problems)
- Insulator bushings (oil levels and bad connections)
- Standoff insulators (moisture, contamination, degradation)
- Lightning arrestors (degradation of metal oxide disks)
- Circuit breakers (oil or SF_6 leakage)
- Mechanical disconnects (bad connections, contamination)
- Control cabinets (wear and tear on fans, pumps, and other components)
- Batteries

Detection of temperature increases in these components with IR cameras allows preventative maintenance operations before an unplanned outage occurs due to outright failure.

Principles of IR Sensing

The first principle of IR sensing is "many components heat up before they fail". Second, all objects emit thermal radiation in the infrared spectrum that is not seen by the human eye. Third, IR cameras convert that radiation to visual images that are calibrated to a temperature scale. This non-contact temperature data can be displayed on a monitor in real time, and can also be sent to a digital storage device for analysis. Measurement accuracy is typically ±2°C.
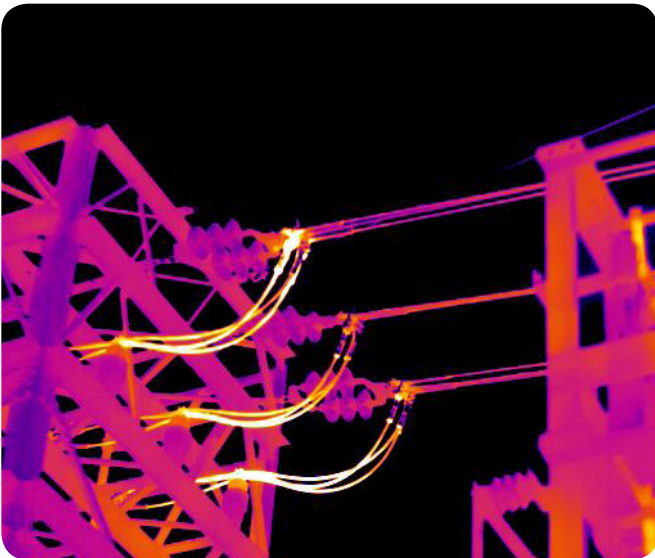
IR video cameras do not require lighting to produce their images, and can see hot spots well before excessive heat or loss of insulation leads to failure. They can see through moisture in the air to obtain good images and relative temperature readings of target objects or monitored areas. They can be mounted in all-weather housings and placed on pan/tilt drive mechanisms to survey large areas of a substation. With different focal length lenses, they can be placed wherever required. Therefore, they support 24/7 monitoring in all types of weather and locations.
FLIR IR cameras recognize differences in the heat signatures of electrical components and the surrounding background (such as the sky or clouds), and can compare the temperatures of similar components in close proximity to one another. Built-in logic, memory, and data communications allow them to compare the temperatures in their images with user-defined settings, and send that data to a central monitoring station for trend analysis, triggering alarms, and generating exception reports. They can even notify facility managers in remote offices of abnormal conditions by triggering an email message. This makes them ideal for unattended monitoring of substation equipment, and detection of unauthorized intruders.

Typical System Configurations

FLIR partners with automation system suppliers to create customized thermal imaging and non-contact temperature measurement systems for electric substations. For instance, FLIR supplies IR cameras to Pivotal Vision, LLC (Minneapolis) for substation monitoring and other applications. Pivotal Vision integrates the FLIR cameras with its pan/tilt housings, and automation software to create the firm's ScadaCam® Intelligent Surveillance systems. These systems can automatically perform site patrols, monitor equipment temperatures, and scan for security breaches without human supervision. The video images and their temperature data are carried over Ethernet, wireless, or fiberoptic cables to an appropriate interface that communicates this data to the central monitoring location. Automation also provides data collection on the operation of equipment without sending people to substations. This provides for better management of assets at a lower cost.

The diagram on the following page depicts a typical substation monitoring system that uses the FLIR A-320 cameras, plus visible light cameras for certain intrusion monitoring applications. A system of this type has been installed at one of Xcel Energy's "Substations of the Future" in Minnesota. The most advanced versions of these systems provide time-stamped 3-D thermal modeling of critical equipment and areas, plus intrusion monitoring with motion detection features. This is just one of many IR camera system arrangements that can be used by electric utilities to join the Smart Grid movement.

Automated Substation Monitoring Systems

Contact FLIR for a free consultation on your monitoring application, and our recommendations for a FLIR camera system and software.

Typical Configuration
One site, multiple remote locations
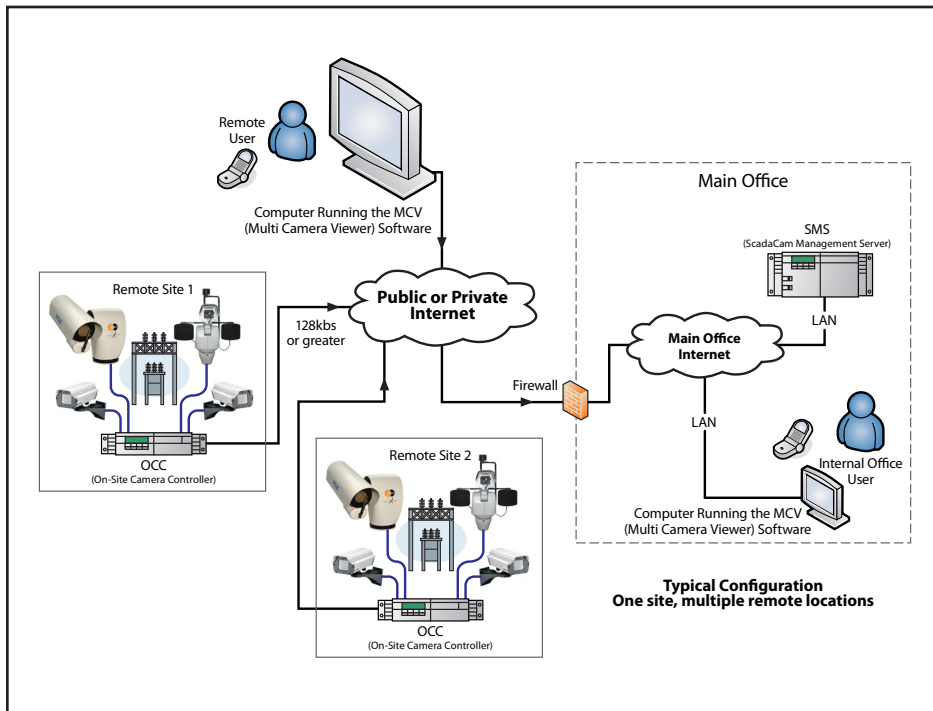
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Camera Specifications

Detector	320×240 pixel uncooled microbolometer focal plane array
IR Spectral Band	7.5 – 13μm
Object Temperature Range (Selectable)	–20°C to +120°C or 0°C to +350°C
Accuracy	±2% or 2°C of reading
Sensitivity	0.07°C at 30°C
Field of View (FOV)	25°(horz.) × 18.8°(vert.)
Focus	Auto and manual with electronic zoom
Min. Focus Dist.	0.4m
Spatial Resolution (Instantaneous FOV)	1.36mrad
Image Update Rate (Selectable)	9 or 30 frames per second
A/D Converter	14-bit
Interfaces	NTSC/PAL video, Ethernet, and Digital I/O (10-30VDC)
Electrical	12/24VDC power
Physical	170x70x70mm, 0.7kg
Mounting	Tripod (UNC ¼"x20) or 2xM4 threaded holes
Environmental	–15°C to +50°C operating range; 2g vib. / 25g shock per IEC 60068-2-6/29
Optional Accessories	Lenses with different focal lengths and FOVs, various housings, and mounting options (consult factory)
Included Software	Allows easy camera setup, alarm configuration, thermal image and temperature data capture, trend analysis, and remote monitoring via Ethernet, ftp, and email.

WE KNOW INFRARED. LIKE NOBODY ELSE.

FLIR invented the infrared camera industry as we now know it. We brought the first commercial IR camera to market in the 1960s and have piled up more industry firsts in thermal imaging than anyone. Today we are the only global company totally dedicated to finding and fixing thermal problems through IR imaging systems. Our company's mission is to provide the most innovative systems available, with the highest possible quality, and show thermography practitioners how to get the most out of them. Our goals, now and in the future, are to provide greater insight into all types of thermal phenomena, and help our customers save money by applying this knowledge. This is supported by the most comprehensive and respected training courses in the industry.

FLIR's 'smart' IR cameras are used in basic research, non-destructive testing, product development, factory automation, equipment and building maintenance, asset protection, medical diagnostics, public safety, national defense, and a host of other applications. No other company offers the breadth of thermal imaging/temperature monitoring products supplied by FLIR, and none is as dedicated to technical excellence as our 350+ engineers. Within the past three years alone, FLIR has spent more than $230 million on R&D. Our customers are the primary beneficiaries of this investment, enjoying an ROI that amounts to millions of dollars a year in direct savings from operating efficiencies and loss avoidance. As a result of this leadership, FLIR is the most trusted name in the industry.

For more information:
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