Gas Insulated Substations (GIS) are often critical assets for most organizations. GIS uses range from industrial applications to utility power generation equipment as well as speciality functions. Managing these assets requires specialized knowledge and a plan to keep up with the demands on today’s maintenance and asset managers.
Proactive asset management is a strategic planning tool that must be looked at much more seriously as O&M (operation and maintenance) budgets decline, additional legislation is being imposed, such as NERC Standard CIP-014-1 (see Power Guide 1, page 6, for an explanation of how of CIP-014-1 applies to asset management), tribal knowledge is retiring, and aging equipment carries more risk if not properly managed. Why proactive asset management? It helps align costs and resources to prevent small maintenance issues from growing into large problems.

Your gas insulated switchgear (GIS) has been installed for ten, fifteen or maybe over thirty years. How will you cost-effectively manage risk and keep it operating reliably? "Cases show that up to 30% of the ‘total cost of ownership’ can be avoided with more effective decision-making about asset life cycles,” Electricity Today. Developing a GIS asset management (AM) plan will improve your return on assets and help meet the rest of your yearly strategic goals. The AM plan described in this paper is meant to serve as an example for improving ROI (return on investment) results. The first three steps may be used as phase one of an AM plan. The latter three steps may be something that is already being implemented or it may be part of phase two of an AM plan.

1. Asset Assessment
Have you had a condition assessment or fleet assessment? With a condition assessment, OEM experts open the doors and perform an on-site, visual inspection on your equipment. With a fleet assessment, OEM experts take a detailed review of maintenance records, fault history, service advisories, commissioning and test records, for an in-depth analysis of the equipment. The OEM also reviews product upgrades to ensure the equipment is up-to-date with the latest operating components and technology. A fleet assessment provides a holistic view of your system, including the criticality of the equipment, spare parts availability, and any recommendations for improvements or upgrades.

Assessments can identify leading indicators on equipment that seems to be operating fine at the moment but may suddenly have a problem that can create downtime, costs and urgent maintenance issues. Rick Gardner, Sales & Marketing Manager
for ABB Medium Voltage Service explains, “An assessment can identify risks and provide a go-forward plan to mitigate them, which includes identifying the highest priority issues that need to be addressed immediately.” While there’s a cost to doing an assessment, the return on that investment is measurable and usually significant.

2. **Spare parts analysis**

After a condition or fleet assessment – it is imperative to consider the necessary spare parts for this critical equipment. Although highly reliable, problems can and do occur with mechanical equipment over time. Some parts have a long lead time by their very nature. ABB recommends identifying the critical components specific to your equipment and stocking the necessary parts or having a contingency plan for sourcing those parts quickly such as holding spares on consignment with the OEM. Although spares are specific to your installation and application, a generally recommended list of strategic and critical components includes:

**Strategic**
- Circuit breaker or Interrupter
- Fast Acting Grounding Switch
- Disconnect and grounding switch
- Operating mechanism (complete)
- Bushing
- Voltage transformer
- Current transformer
- Surge arrester
- Transformer bushing and end box
- Cable terminations and end box
- Busbar and compensator

**Critical**
- Seals
- Coils
- Motors
- Brush kit
- Density monitor
- Barrier and support insulator
- Pressure relief device
- Grease and consumables

Sample asset assessment chart indicating which assets are healthy or at-risk. This plus data is used to develop and implement a plan to improve fleet reliability.

GIS bay maintenance after an asset assessment

Example strategic component, complete HMB mechanism
4. Radiography
Radiography is the X-ray inspection of critical, internal components. Almost everything on the GIS can be inspected without disrupting the gas chamber or internal components utilizing radiography. This includes 69 to 550 kV GIS of any OEM brand. When combined with SF$_6$ gas analysis and mechanical/electrical testing, it is the most cost-effective and comprehensive way of determining the equipment’s reliability and integrity of internal components. Radiography not only significantly reduces the outage time and cost, it also eliminates the risks of SF$_6$ emissions or environmental contamminates entering the equipment. See case study on page 5 for more information.

3. Preventive Maintenance
Preventive maintenance is a key factor in maximizing the life of any GIS, regardless of brand or rating. See Power Guide 2 (page 7) for a generally recommended maintenance schedule. Preventive maintenance is both low cost and high impact. Small actions, such as SF$_6$ gas testing gives powerful insight into the health of the equipment. If the gas is “clean,” i.e., no decomposition elements (SO$_2$), it indicates the GIS has not had any faults, or if no or extremely little moisture is found it likely has no leaks. According to John Dalton’s partial pressure law, when SF$_6$ leaks from equipment, air enters to equalize pressure introducing moisture to the system. Gas moisture should be below the OEM recommendation – check the instruction manual to verify the ppm (parts per million) level for your specific GIS. Visual inspections are another example of where leading indicators may be found, such as checking counters for excessive mechanism pump starts, inspecting the condition of rubber boots to ensure joints are protected from the weather, or looking for unexpected oil leaks.

Studies show that corrective maintenance can cost **ten times more** than preventive maintenance.

5. Review of condition monitoring data
Data is extremely powerful. It can often tell you something you do not realize at first. How are you using the data your equipment provides? Do you review it on a regular basis or only when an event occurs? Do you need help reviewing the data from your equipment? OEM experts can determine leading indicators, or clues, by reviewing KPI’s before a problem occurs. If your equipment does not have a monitoring system, one is easily retrofitted which continuously watches and alerts you to problems and the status of key factors including, SF$_6$ gas level, interrupter wear, coil continuity, mechanism charging system, close and trip coils, heaters, and coil signature analysis. Data should be accessible remotely with historical records of events logged for root cause analysis.

**Radiographic Inspection Images**
Asset Monitoring
A customer in South America with a fleet of 550kV 30 year old BBC GIS contacted ABB to implement a reliability centered program built around condition monitoring, data analysis, and spare parts inventory management. A pilot was installed to demonstrate the product functionality. The asset monitoring portion of the project included equipment monitoring devices, sensors, local training, and additional support services. The local service center collaborated to develop a solution for the legacy equipment which will keep it reliable well into the future at a cost that is far less than alternative options. Data from condition monitoring devices allows for strategic as well as proactive decision making for prioritizing maintenance to the assets that need it while leaving assets alone that are healthy. It also assists replacement planning of failing assets.

Upgrade & Retrofit
The EGL 380 kV substation at Filisur, in Switzerland, is the first substation in the world to have such a specifically developed retrofit breaker installed. The utility had originally considered an overhaul of their HKA 8 mechanism, but decided instead to install the new HMB 8 mechanism. They also replaced their complete SL3-2 breaker and mechanism with a newly developed retrofit SP 3-1 breaker. This new breaker has only one single arcing chamber – representing state-of-the-art GIS technology – and therefore needed only a (smaller) HMB 4 mechanism. The utility quickly opted for this proposal – extended substation life, continued availability of spare parts and lower maintenance costs being the convincing arguments. The actual circuit breaker exchange at the site took only two days and the equipment resumed normal operations with minimal downtime.
A highlight of NERC-CIP-14-01 includes the following aspects:

- Requires owners and operators of Bulk-Power Systems to perform a risk assessment of their system to identify critical facilities and critical assets
- Evaluate potential threats to, and vulnerabilities of, those facilities
- Develop and implement a security plan to protect against attacks on those facilities

This standard applies to all substations that are rated at or above 500 kV, as well as any transmission facility operating between 200 and 499 kV at a single station where it is connected at 200 kV or higher to three or more stations.

Good data is the key to success. Real-time data, easily accessible, and error-free data which is automatically collected and interpreted by a system which understands GIS is necessary. According to Randy Schrieber, VP of ABB Power Services, there are two types of equipment on which monitoring efforts should be focused, “the larger the asset or the more critical its role in your transmission system, the greater the benefit from asset monitoring.” With a condition and remote monitoring system, maintenance cycles are extended, problems are predicted, work is easier to schedule when resources are available, or when resources are available at a lower cost avoiding emergency call-outs, and failures can be avoided through data trending. Schrieber added, “Organizations using condition monitoring have seen their maintenance budgets fall by 20 to 25% by focusing on the at-risk assets.”

6. Upgrades and retrofits
Upgrades and retrofits keep the existing footprint, reduce risk, enhance reliability, and extend equipment life while improving spare parts availability with improved performance by replacing discrete components with new technology. As pictured below, upgrading oil cables with solid state dielectric cables eliminates the risk of oil leaks and reduces future maintenance costs.

**Common GIS Upgrades & Retrofits:**

<table>
<thead>
<tr>
<th>Mechanisms</th>
<th>HV Cables</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT’s/PT’s/CCVT’s</td>
<td>Interrupter Upgrades</td>
</tr>
<tr>
<td>Surge Arresters</td>
<td>Rupture Disk</td>
</tr>
<tr>
<td>Condition Monitoring Device</td>
<td>Custom or Specialty Upgrade &amp; Retrofits</td>
</tr>
<tr>
<td>SF₆ Plumbing</td>
<td>Weather Upgrades</td>
</tr>
<tr>
<td>Density Monitor</td>
<td>Animal Control</td>
</tr>
</tbody>
</table>

Figure 1: Oil Cables  
Figure 2: Upgraded Dielectric Cables
Power Guide 2 – Recommended Maintenance

Indoor GIS

- Yearly visual inspection on GIS bays & mechanism to follow instruction book recommendations
- Five-year SF₆ gas analysis
- Intermediate maintenance performed at five years
- Major maintenance to follow condition-based and application-based guidelines

Outdoor GIS

- Yearly visual inspection on GIS bays & mechanism to follow instruction book recommendations, looking for signs of corrosion, water ingress, UV deterioration and animal damage.
- Five-year SF₆ gas analysis
- Intermediate maintenance performed at seven years
- Major maintenance to follow condition-based and application-based guidelines

Conclusion

Asset managers must play a critical balancing act – minimize the cost of maintenance while maximizing asset availability. Implementing an AM plan will not improve reliability, reduce risk, and cut costs overnight. It is a multi-step process that is best developed with a roadmap having multiple milestones for improvement. Improving your return on assets is a challenging task. ABB OEM experts are available to help develop your AM roadmap or support it where needed.
Co-Author Profile

Paulo Kueffner is the GIS Business Manager for ABB High Voltage Service (US) who has more than 30 years of experience in high voltage equipment, field service, project management, and GIS. Paulo has held several roles in ABB’s field service department in Brazil and USA. He has installed and inspected over 200 AIS and GIS bays. He specializes in assessing, maintaining, retrofitting, and life extending GIS.

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Sources

Electricity Today Magazine, January, February edition

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