

Office of the Assistant Secretary of Defense
(Energy, Installations, & Environment)



**Energy Resilience: Operations,
Maintenance, & Testing (OM&T)
Strategy and Implementation Guidance**

March 2017

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Introduction.....	4
Purpose.....	5
Benefits of an OM&T Strategy and Program	5
Elements of an OM&T Program.....	7
Considerations to Develop an OM&T Program	9
Guidance for Compliance to OM&T Requirements	12
Operations.....	12
Introduction.....	12
Standard Operating Procedures (SOP).....	12
Electrical Operating Procedures (EOP)	12
Electrical Safe Work Practices (ESWP)	13
Maintenance.....	14
Introduction.....	14
Routine Maintenance	14
Full-Scale Maintenance.....	15
Testing	16
Introduction.....	16
Routine Testing.....	16
Full-Scale Testing	17
Integrated System Test (IST)	18
Acronyms.....	20
Definitions.....	21

Figures

Figure 1 - Adequate and Timely Performance of Maintenance and Repairs over Time.....	6
Figure 2 - Elements of an Effective OM&T Program.....	7
Figure 3 - Elements of an Effective Electrical Safe Work Practice	13

Appendices

Appendix A – OM&T Commitment Memo
Appendix B – Energy Resilience Verification and Funding Memo
Appendix C – Management Checklist for an OM&T Program
Appendix D – Base-level Generator Operating Log Example
Appendix E – Supplemental Technical Documentation

Introduction

The Department of Defense (DoD) has published policy on energy resilience in its Department of Defense Instruction (DoDI) 4170.11, *Installation Energy Management*. Installation energy resilience is the ability to prepare for and recover from energy disruptions that impact mission assurance on military installations. Energy resilience can be achieved in a number of different ways, to include redundant power supplies (generators); integrated or distributed fossil, alternative or renewable energy technologies; microgrid applications and storage; diversified or alternate fuel supplies; upgrading, replacing, operating, maintaining, or testing current energy generation systems, infrastructure, and equipment; as well as mission alternatives such as reconstitution or mission-to-mission redundancy. The following guidance describes the operations, maintenance, and testing (OM&T) aspects of energy resilience.

The following guidance was developed in collaboration with DoD Components to assist in the implementation of energy resilience requirements published on March 16, 2016 in DoDI 4170.11. DoDI 4170.11 requires DoD Components to take necessary steps to ensure energy resilience on military installations. DoDI 4170.11 requires that, *“In collaboration with DoD Components, the ASD(EI&E) shall issue supporting technical and budgetary guidance to assist DoD Components in prioritizing energy resilience decisions, and shall update and provide this guidance annually.”*

This OM&T strategy and implementation guidance provides DoD the capability to ensure available, reliable, and quality power to continuously accomplish DoD missions from military installations and facilities. This OM&T guidance will assist installation commanders, mission owners, operations and maintenance staff, utility managers, energy managers, and other installation support personnel on military installations and at facilities to collaborate and ensure the appropriate OM&T for energy resilience. This guidance was primarily developed by consolidating existing processes and procedures for OM&T of energy resilience systems and infrastructure, acknowledging that many policies and requirements already exist.

The intention of this implementing guidance is to raise awareness of the importance of efficiently and effectively performing OM&T to reduce risks and vulnerabilities to continuously accomplish critical mission operations. Critical mission operations can include defense critical infrastructure (DCI), Service and Defense Agency warfighting missions, emergency, recovery, and response missions, and supporting installation infrastructure that align to these missions. DoDI 4170.11 requires that, *“DoD Components shall clearly define, identify, and update critical energy requirements that align to critical mission operations in collaboration with tenants, mission owners, and operators of critical facilities on military installations.”*

Energy resilience aligns to Department of Defense Directive (DoDD) 5100.01, Functions of the Department of Defense and Its Major Components. It supports the core mission areas of the Armed Forces, which are broad DoD military operations and activities required to achieve strategic objectives of the National Security Strategy, National Defense Strategy, and National Military Strategy, in accordance with title 10, United States Code.

Purpose

This guidance provides installation commanders, mission operators, operations and maintenance staff, utility managers, energy managers, government contractors and subcontractors, and installation support personnel procedures to ensure that energy generation systems, infrastructure, equipment, and fuel are available and reliable to support critical mission operations on military installations. As appropriate, it should be used to align to the appropriate energy sources impacted by the OM&T requirements contained in this document, whether electric or thermal sources. It can also be used to shape further technical guidance and procedures to ensure the appropriate OM&T is conducted on energy resilience systems that align to mission requirements.

This guidance includes: (1) an overview of OM&T for energy resilience systems and infrastructure; and (2) detailed appendices on OM&T procedures. The overview (pages 1 to 23) provides guidance for mission operators and installation support personnel that describes challenges associated with owning, operating, maintaining, and testing energy resilience systems and infrastructure. The appendices provide specific processes and procedures which can be used to help manage OM&T for energy resilience systems and infrastructure. The appendices refer to industry and DoD best practices, and include procedures, templates, and techniques already being used by some DoD Components. These best practices were collaborated and coordinated through the Energy Resilience Working Group (ERWG), and can be shaped to align with a DoD Component's unique organizational mission, processes, and procedures. For further details on the Department's Energy Resilience Program, please see the following: http://www.acq.osd.mil/eie/IE/FEP_Energy_Resilience.html.

For a successful OM&T program, DoD Components should ensure integration of senior leadership and management as they establish strategies, processes, and procedures. The following initiatives will foster the development of strategies, processes, and procedures in support of an OM&T vision and help to advocate for funding: (a) development of an OM&T mission statement to clarify objectives; (b) implementation of an OM&T plan and management/stakeholder commitments; (c) Operations, Maintenance, Engineering, Training, and Administration (OMETA) (discussed later in this document); and, (d) development and execution of meaningful metrics to measure performance.

Benefits of an OM&T Strategy and Program

The safety and reliability of a power system largely depends on its OM&T strategy. OM&T is a cost-effective approach to improve system performance and enhance reliability. A benefit of a well-constructed OM&T strategy and a supporting program is energy savings, along with reliability improvements. OM&T programs improve energy efficiency performance and are estimated to save 5% to 20% on energy bills without a significant capital investment, meaning immediate savings can be achieved with minimal capital investment. OM&T also costs approximately 20 times less than retrofits and achieves roughly the same energy savings. (PNNL, 2010)

An OM&T program also extends the useful life of equipment. Figure 1 shows the effect of adequate and timely maintenance and repairs on the service life of mechanical and electrical equipment. It highlights how performance and components will degrade over time in a maintenance and non-maintenance scenario. Figure 1 does not factor in the additional benefit of reduced building (energy) operating costs resulting from effectively maintaining mechanical and electrical equipment.

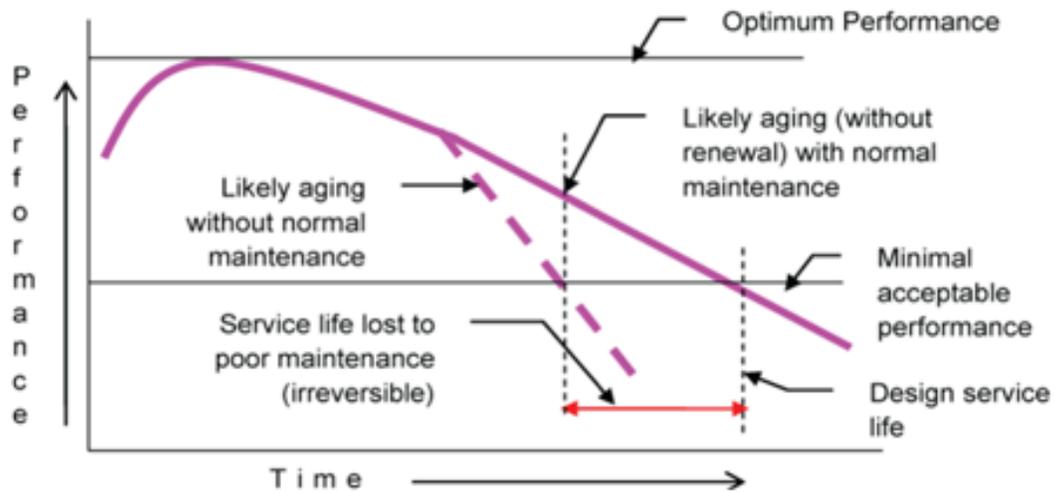


Figure 1 - A Graphical Representation of Adequate and Timely Performance of Maintenance and Repairs over Time
 (Source: NASA, 2016)

Beyond the potential for significant energy savings, OM&T has other important implications:

- a) OM&T promotes safety and occupational health. Maintaining and testing equipment mitigates potential hazards arising from equipment failure.
- b) Maintaining and testing circuit breakers, trip units, and relay protection ensures that protective devices operate as designed and within opening times. Additionally, OM&T ensures that the personal protective equipment (PPE) used by workers is appropriate for the work to be performed.
- c) In most facilities, the OM&T staff are responsible for not only the comfort, but also the risks associated with indoor air quality (IAQ) standards. OM&T provides personnel the capability to deal with these IAQ standards.
- d) Properly performed OM&T ensures that equipment will meet or exceed its designed life expectancy. Conversely, the costs of early equipment failure are usually high, not budgeted for, and results if OM&T is not performed at a sufficient quality.
- e) OM&T improves customer service to critical mission operators by establishing a collaborative process for scheduled maintenance, and minimizing downtime to mission over the life of the systems that are maintained and tested.
- f) OM&T processes allow for the proactive management of vulnerabilities and risks to energy resilient systems and infrastructures. These could include reliability (e.g., equipment failure or weather-related) or man-made (e.g., physical or cyber) threats.
- g) Effective OM&T allows for compliance with local, state, and Federal regulations.

Elements of an OM&T Program

A successful O&M program contains five integral and integrated elements: operations, maintenance, engineering, training, and administration (OMETA).



Figure 2 - Elements of an Effective OM&T Program
(Source: Meador, 1995)

Operations

- a) Administration – to ensure effective implementation and control of operation activities. Standard Operating Procedures (SOP), Electrical Operating Procedures (EOP), and Electrical Safe Work Practices (ESWP) should be used to effectively document and administer an OM&T program (see page 12, Operations section for SOP, EOP, and ESWP definitions).
- b) Conduct of Operations – to ensure efficient, safe, and reliable process operations.
- c) Equipment Status Control (Supervisory Control and Data Acquisition (SCADA)/Building Management Controls (BMC)) – to be cognizant of the status of all equipment.
- d) Operator Knowledge and Performance – to ensure that operator knowledge and performance will support safe and reliable plant operation.

Maintenance

- a) Administration – to ensure effective implementation and control of maintenance activities.
- b) Work Control System – to efficiently and safely control the performance of maintenance so that plant operation is economical, safe, and reliable.
- c) Conducting Maintenance – to conduct maintenance in a safe and efficient manner.
- d) Preventive Maintenance – to contribute to optimum performance and reliability of plant systems and equipment.
- e) Maintenance Procedures and Documentation – to provide directions, when appropriate, for the performance of work and to ensure that maintenance is performed safely and efficiently.

Engineering

- a) Engineering Support Organization and Administration – to ensure effective implementation and control of technical support.
- b) Equipment Modifications – to ensure proper design, review, control, implementation, and documentation of equipment design changes in a timely manner.
- c) Equipment Performance Monitoring – to perform monitoring activities that optimize equipment reliability and efficiency.
- d) Engineering Support Procedures and Documentation – to ensure that engineering support procedures and documents provide appropriate direction and support the efficiency and safe operation of the equipment.

Training

- a) Administration – to ensure effective implementation and control of training activities.
- b) Employee Training – to ensure that plant personnel have an understanding of their responsibilities and safe work practices, and have the knowledge and practical abilities necessary to operate the plant safely and reliably.
- c) Training Facilities and Equipment – to ensure the training facilities, equipment, and materials effectively support training activities.
- d) Operator Training – to develop and improve the knowledge and skills necessary to perform assigned job functions.
- e) Maintenance Training – to develop and improve the knowledge and skills necessary to perform assigned job functions.

Administration

- a) Organization and Administration – to establish and ensure effective implementation of policies and the planning and control of equipment activities.
- b) Management Objectives – to formulate and utilize formal management objectives to improve equipment performance.
- c) Management Assessment – to monitor and assess activities to improve all aspects of equipment performance.
- d) Personnel Planning and Qualification – to ensure that positions are filled with highly qualified individuals.
- e) Industrial Safety – to achieve a high degree of personnel and public safety and occupational health.

Considerations to Develop an OM&T Program

Diagrams and schematics

An important consideration in OM&T is to ensure that all electrical one-line diagrams, schematic/control, and riser diagrams are easily accessible and updated. These diagrams are road maps for OM&T and ensure safety and reliability of energy systems (electrical and thermal systems). They are also the primary tools for performing work on equipment delivering energy to an electrical system. Without these diagrams, OM&T of an energy system and its supporting infrastructure will be extremely difficult to conduct effectively.

Acceptance testing, studies, and modeling: Benefits and Challenges

Another important initial consideration for OM&T is to evaluate an energy system's compliance with existing requirements. This can be accomplished through acceptance and maintenance testing, and supported through overcurrent protective coordination (OPC), electrical system studies, and modeling software. Appendix E1 provides an example of how to specify an electrical system study, manage updates, and ensure quality control of the study for a base, campus, or facility.

Acceptance and maintenance records are vital to support establishing a baseline to help develop an OM&T strategy and program. These records provide information for study and model inputs, and help to compare past and future data. PowerDB and other similar acceptance and maintenance test data management software can be used to create a standard method to assess energy systems. Additionally, maintenance schedule software such as Maximo is also important to assist in OM&T on a common and standard platform. Software tools such as Maximo Asset Management allow organizations to share and oversee best practices, and to manage its inventory, resources, personnel, plant, production, infrastructure, and facilities.

System models that incorporate the entire base, campus, or facility electrical and thermal systems provide easy access to one-line diagrams, protection settings, and incident energy levels in a single controllable location. These models help to determine power flow, short circuit values, and work permit information. They also assist in the management of control and protection device settings, and ensure settings are adequately set to the appropriate standards. Power system models could also incorporate schematic diagrams, riser diagrams, panel schedules, and geospatial drawings. Geospatial drawings could be helpful in identifying the location of electrical equipment and manholes.

Some bases, campuses, or facilities may not be able to standardize their OM&T, and the supporting power system studies and modeling due to existing long-term contracts. For example, utility privatization (UP) contracts may present a near-term challenge to improve the reliability of existing energy infrastructure since energy resilience was not negotiated into the existing contract. For future privatized utilities, consideration should be given to include OM&T in the contract to better ensure the energy resilience of the system, as appropriate.

For bases, campuses, or facilities that have an existing UP contract, DoD personnel managing and overseeing these systems and infrastructure should approach their utility provider to review the extent of the OM&T plan within the existing contract. If the existing utility provider is implementing traditional

OM&T standards (such as those described in this guidance), then base personnel should request the one-line diagrams, studies, models, and reliability metrics to verify the utility provider's performance and to ensure available and reliable power in accordance with Federal and industry standards. If the utility provider does not have an OM&T strategy, plan, verification, or performance metrics in place - the base, campus, or facility should consider independently overseeing and monitoring an OM&T process, or independently implementing power system models, studies, verification, and performance metrics to ensure the resilience of its generation systems and infrastructure, as needed. It should be noted that UP contracts traditionally have not included energy resilience in the form of generation systems, but should already include OM&T standards for the infrastructure on the base, since improving the reliability of the distribution system is a primary objective of UP.

Acceptance testing, studies, and modeling: Typical technical requirements

During acceptance or maintenance testing, all protection relays, circuit breaker protection, and controls are typically set in accordance with an OPC and arc flash study, which is performed and stamped by a registered professional engineer (PE). Where available, arc flash reducing maintenance switches (ARMS) or other similar features should be set to reduce the incident energy level to its lowest possible level. A personal protective equipment (PPE) level of 2 is also typically preferred. Where ARMS features are not available, the instantaneous function (or alternatively, zone selective interlocking) is used to reduce the incident energy to the lowest level possible while still maintaining coordination of the system. Enabling the instantaneous function will reduce the incident energy level during maintenance periods. This increases safety for operators and in the event of a system fault, reduces the amount of damage sustained to equipment and minimizes mission downtime.

Electrical system studies are performed by the PE¹ and utilize commercially available software specifically designed for acceptance testing and continuous OM&T. The electrical study should be performed with an electrical system modeling software, and use that same software for future OM&T management. It is important to use the same standard software tool to avoid integration issues and to be able to compare results with future maintenance and testing. Base and facility personnel managing energy resilient systems should consider software tools that are flexible and are able to scale to current and future energy generation systems (e.g., generators) and the necessary electric devices that align to mission needs. It should be noted that some modelling software may have bus limitations and may not be able to model specific energy generation systems or electric devices.

During the electrical study, base and facility personnel should also ensure correct control and operation of devices other than protective devices. These include, but are not limited to, the coordination of dual source roll-over schemes (e.g., automatic closing and opening of a main-tie-main), automatic transfer switches, static bypass switches, as well as pick-up and timing settings for under voltage, distance, reverse power, and bus differential relays.

¹ In general, a PE is the required approach supported by NFPA standards. However, NFPA technical standards should be reviewed to also accurately assign "qualified engineers" to perform the appropriate tasks.

Acceptance testing, studies, and modeling: Typical personnel and organizational requirements

Electrical equipment should be accepted, maintained, and tested by an International Electrical Testing Association (NETA) independent testing company (see <https://www.netaworld.org>) or by National Institute for Certification in Engineering Technologies (NICET) (see <https://www.nicet.org>) certified technicians. A NETA Level IV or NICET level IV technician should be present and supervise all testing to ensure that tests are performed correctly and recorded properly in a maintainable test record. Software such as PowerDB (see <https://www.powerdb.com>) or other similar software is also suggested to oversee and manage OM&T requirements.

There are a number of benefits in using NETA and NICET accredited companies. NETA accredited companies are independent electrical power system testing service providers and are divested of competing service or manufacturing interests. As third-party auditors, they provide unbiased electrical testing results while ensuring accurate testing and reporting. They also are not influenced by conflicting factors involved with budgeting, installation, or product manufacturing.

NICET certified technicians could also be used as alternatives to NETA certified technicians. NICET's procedure for recognizing qualified engineering technicians and technologists is nationally recognized and accepted. NICET personnel provide similar benefits as NETA personnel. They provide unbiased technical assurance of electrical testing results and help avoid conflicts of interest that may arise with vendors. NICET certified technicians could be military or civilian personnel. It should also be noted that an installer is prohibited from self-performing acceptance or maintenance testing because it would violate the terms of an independent third-party activity. NETA and NICET provide an avenue to avoid these violations, as they are independent third-party organizations.

Establishing Initial Strategy, Planning, and Management Structure: Templates, Checklists, and Tools

In order to effectively oversee and manage an OM&T program, the appropriate processes and procedures should be implemented that fit an organization's mission needs. This guidance provides templates, checklists, and tools which help apply and institutionalize an OM&T program. These checklists provide examples which can be considered to ensure OM&T on energy resilient systems and infrastructure. The following organizational templates, checklists, and tools should be considered when developing processes and procedures to implement OM&T strategies and plans across an organization:

- a) Appendix A – OM&T Commitment Memo
- b) Appendix B – Energy Resilience Verification and Funding Memo
- c) Appendix C – Management Checklist for an OM&T Program
- d) Appendix D – Base-level Generator Operating Log Example
- e) Appendix E – Supplemental Technical Documentation

Guidance for Compliance to OM&T Requirements

The following section reviews existing OM&T requirements for the DoD. The following section can be used as a starting point for personnel to improve energy resilience on military installations, and to begin institutionalizing processes and procedures to manage and oversee energy resilience. The following section is separated into three main topics: (1) operations; (2) maintenance; and, (3) testing.

Operations

DoDI 4170.11 requires that, “*DoD Components shall ensure that primary power and emergency energy generation systems, infrastructure, equipment, and fuel that support their critical energy requirements receive the necessary maintenance. At a minimum, DoD Components shall maintain primary power and emergency generation systems according to their technical specifications and ensure that there is a trained operator² assigned to maintain the energy generation system, infrastructure, equipment and fuel.*”

Introduction

In order to ensure a safe work environment and reduce unscheduled outages due to operational errors, personnel who operate an electrical system should be trained. Existing SOPs, EOPs, and ESWPs provide the means to apply safe and effective operations practices. The application of SOPs and EOPs ensure that requirements are performed according to best practices, and should be used to establish well-structured, and consistent processes. The application of these procedures through a continuous improvement process is critical for organizational acceptance and to measure life-cycle performance. Institutional processes and procedures for OM&T will help train, educate, and impact behaviors to improve operations, comply with standards, reduce costs, and ensure performance across the organization. Accepted processes and procedures should not be general guides. For example, they should document specific OM&T activities that are required to measure organizational and personnel performance. The following provides further details and examples that organizations and personnel can use to establish processes to ensure that energy resilient systems and infrastructure operate appropriately.

Standard Operating Procedures (SOP)

SOPs should include all aspects of a work activity to be performed. SOPs differ in their primary focus areas, as they can range from switching operations on medium- and high-voltage switchgear, to planning for emergencies. SOPs can also range from the simple operations of a small system to a detailed process for operations on large campuses or bases with multiple critical facilities. Appendix E2 gives examples of SOP structures and provides a framework for modifying them to organizational and mission needs.

Electrical Operating Procedures (EOP)

EOPs are a subset of SOPs and have a more specific task-oriented focus. An EOP focuses on a specific action that a worker performs, and it describes how to prepare for or perform work on equipment. For example, it can describe how personnel would test PPE and how personnel would rack out a low-

² Trained operator implies that there are qualified persons performing the work in accordance with manufacturer’s equipment maintenance and procedures, NEC, NFPA 70E and OSHA requirements.

voltage power circuit breaker. Appendix E3 gives examples of EOPs which could be used by personnel to address OM&T requirements and to develop future EOPs.

Electrical Safe Work Practices (ESWP)

ESWP is another important consideration when conducting OM&T on energy resilient systems, equipment, and infrastructure. It is important to encourage behavioral acceptance of electrical safety across the OM&T program. This includes encouraging ESWP in system studies, and providing management controls and tools for organizational acceptance (e.g., safety training, incorporating safety within existing SOPs and EOPs, or developing independent safety SOPs and EOPs). Finally, adopting ESWPs when performing system maintenance or testing on generation systems or on equipment is also important. Figure 3 below provides an overview of important ESWP elements.



Figure 3 - Elements of an Effective Electrical Safe Work Practice

To achieve organizational acceptance, electrical safety requires commitment from senior leaders and operators across the entire organization. These commitments can be addressed early-on in the OM&T process by documentation through an ESWP document (see Appendix E4 for an example ESWP document) signed by the Authority Having Jurisdiction (AHJ) or the Designated Agency Safety and Health Official (DASHO). An ESWP document should be developed to inform military, civilian, and contractor personnel performing work to fully understand the expected safety procedures and protocols applicable to the base, campus, or facility. It should outline how the work will be performed safely on the site.

A safety program should ensure that qualified personnel perform or supervise ESWPs. The qualified person must also have working knowledge of short circuit values in an electrical system and the effect of device opening times, since these play an important role to understand arc flash incident energy levels. Organizations should consider the following elements when pursuing and implementing ESWPs: training, PPE, dedicated meetings, lock out/ tag out, as well as the establishment of SOPs and EOPs.

Cultural adoption of safety within an organization also is important, and requires that personnel within an organization appropriately apply established ESWPs. For example, this includes comprehensive application of safety to electrical work to having a step ladder available to perform the electrical task. It is important to ensure that ESWPs are sustained for continuous improvement and evaluation by management and personnel to promote a safety program.

Maintenance

DoDI 4170.11 requires that, “*DoD Components shall ensure that primary power and emergency energy generation systems, infrastructure, equipment, and fuel that support their critical energy requirements receive the necessary maintenance. At a minimum, DoD Components shall maintain primary power and emergency generation systems according to their technical specifications and ensure that there is a trained operator assigned to maintain the energy generation system, infrastructure, equipment and fuel.*”

Introduction

Maintenance intervals for energy systems, infrastructure, equipment, or fuel will depend on mission criticality and the environment in which they operate. Mission critical systems and equipment should have more frequent maintenance intervals. The frequency of maintenance and testing intervals can be reviewed at Appendix C.

Disruption to mission should not be used as an excuse for not performing maintenance. However, if maintenance is not performed due to mission concerns, then the approving or accountable authority (the appropriate installation and/or mission authority) making the decision to forgo the maintenance would sign the maintenance documents or logs (see Appendix B and D for a template to document risk acceptance). This will better document the approving or accountable authority that would be held responsible for any future risk to energy systems and equipment that could lead to mission failure as a result of forgone maintenance. This approach should also be applied when documenting testing of energy systems, infrastructure, equipment, or fuel.

Maintenance of electrical systems can be broken down into routine and full-scale maintenance. The following section will describe these two types of maintenance.

Routine Maintenance

Routine maintenance³ is implemented to ensure equipment maintains its intended function over its useful life. It is also typically required in order to comply with manufacturer warranties. Routine maintenance should be performed in accordance with manufacturer specifications for the following electrical systems. This list is primarily for electrical systems, but other energy systems (such as those referenced in this guidance) also require both routine and preventative maintenance. This guidance and list should be used to shape the appropriate OM&T consideration for all energy systems.

³ Preventative maintenance should also be a consideration in an energy resilience OM&T plan. It ensures the systematic inspection, detection, and correction on equipment to prevent failure before it occurs.

- a) Switchgear and switchboard assemblies
- b) Transformers: dry-type, air-cooled, low-voltage, small, dry-type, air-cooled, large transformers, liquid-filled
- c) Cables: low-voltage, low-energy, 600 volt maximum, medium- and high-voltage
- d) Metal-enclosed busways
- e) Switches: air low and medium voltage metal-enclosed switches , air medium- and high-voltage open switches, oil medium-voltage switches, vacuum medium-voltage switches, SF₆ medium-voltage switches, and fused cutouts
- f) Circuit breakers: air insulated-case/molded-case low-voltage and medium voltage circuit breakers, oil medium- and high-voltage circuit breakers, vacuum medium-voltage circuit breakers, and SF₆ circuit switchers
- g) Electromechanical, solid-state, and microprocessor-based protective relays
- h) Instrument transformers
- i) Metering devices
- j) Regulating apparatus: step-voltage regulators, induction regulators, current regulating apparatus, load tap-changers
- k) Grounding systems, ground-fault protection systems
- l) Rotating machinery, AC induction motors and generators, rotating machinery, synchronous motors and generators, rotating machinery, DC motors and generators
- m) Motor control: motor starters, low-voltage and medium voltage motor control motor starters, low-voltage motor control, motor control centers, medium-voltage adjustable-speed drive systems
- n) Direct-current systems: flooded lead-acid batteries, nickel-cadmium batteries, valve-regulated lead-acid batteries
- o) Direct-current systems: chargers and rectifiers
- p) Surge arresters: low-, medium-, and high-voltage surge protection devices
- q) Capacitors and reactors: capacitors, capacitor control devices, dry-type and liquid filled reactors (shunt and current-limiting)
- r) Outdoor bus structures
- s) Emergency systems: engine generator/uninterruptible power systems/automatic transfer switches
- t) All applicable electrical equipment on installation or facility requiring full-scale maintenance as recommended by manufacturer

Routine maintenance may require that outages occur to electric equipment. Personnel should schedule maintenance outages appropriately and ensure the base, campus, or facility impacted have continuous power or the outage is limited based on mission requirements. During early stages of developing an OM&T program (e.g., during design), the outage impacts related to maintenance should be considered, to include establishing prioritization for critical versus non-critical loads to align maintenance schedules with mission requirements.

Full-Scale Maintenance

Full-scale maintenance will require either a continuous or momentary interruption to power, and it is often performed in conjunction with full-scale testing. NETA maintenance testing specifications (MTS) provide specific guidance regarding the maintenance requirements for individual equipment (Appendix E5). Typically, full-scale maintenance is performed on all major systems and equipment on a

rotational basis every 3 to 5 years, based on the operational environment and criticality of the mission. For systems and equipment in harsher environments or higher criticality missions, a 3-year cycle is typical. Full-scale maintenance tests include visual and mechanical inspections, operational tests, and electrical tests on the same list of equipment provided in the routine maintenance section.

Testing

DoDI 4170.11 requires that, “DoD Components shall conduct full-scale and routine testing of emergency and standby energy generation systems, infrastructure, equipment, and fuel that support their critical energy requirements. A full-scale test includes operating all associated emergency and standby energy generation systems, infrastructure, equipment, and fuel at full operational loads while completely separated from the primary source of power. DoD Components may also elect to substitute a black-start test for a full-scale test. Routine tests include operating all associated emergency energy generation systems, infrastructure, equipment, and fuel at full operational loads while still coupled with the primary source of power. At minimum, a full-scale test shall be conducted on an annual basis and routine tests shall be conducted semi-annually. Routine testing shall be conducted on a monthly basis for emergency and standby generation at DCI facilities.”

Introduction

Testing intervals for energy systems, infrastructure, equipment, or fuel will depend on mission criticality and the environment in which they operate. Mission critical systems and equipment should have more frequent maintenance intervals. The frequency of maintenance and testing intervals will vary based on factors such as manufacturer specifications and mission requirements. A guide for maintenance and testing can be reviewed at Appendix C. Minimum requirements are established in DoDI 4170.11.

Disruption to mission should not be used as an excuse for not performing testing. However, if testing is not performed due to mission concerns, then the approving or accountable authority (the appropriate installation and/or mission authority) making the decision to forgo the testing would sign the testing documents or logs (see Appendix B and D for a template to document risk acceptance). This will better document the approving or accountable authority that would be held responsible for any future risk to energy systems and equipment that could lead to mission failure as a result of forgone testing. This approach should also be applied when documenting maintenance of energy systems, infrastructure, equipment, or fuel.

Testing of electrical systems can be broken down into routine, full-scale, or integrated (blackstart) testing. The following sections will describe these three types of testing.

Routine Testing

Routine testing is typically not invasive and can be performed on a regular monthly cycle. Maintenance on energy systems and associated infrastructure can be performed in conjunction with routine testing to cost-effectively optimize system performance. The following are minimum recommendations to perform during routine testing:

- a) Visual and operational tests to sustain and maintain equipment

- b) Ultrasonic scanning to identify the presence of corona discharges in high-voltage compartments and overhead lines
- c) Battery maintenance and testing
- d) Motor monitoring

Appendix C provides further guidance into testing associated with secondary injection testing of protection relays and circuit breakers, and thermographic (infrared) scanning to identify loose, unbalanced loads or overheated connections.

Full-Scale Testing

Full-scale tests should be performed on a rotational basis. The extent of what can be performed depends on the size of the system and supporting infrastructure. The timeframe between maintenance and testing of equipment typically does not exceed four years. If electrical infrastructure is tied to critical facilities or harsher operational environments, intervals are shortened to maintain and improve reliability.

Full-scale tests require planned outages of systems and equipment over an extended timeframe. Extended interruptions should not occur for facilities that have redundancy available. However, these facilities may experience an intermittent interruption of power to switch to the alternative source of power. This switch over to the redundant power supply should be part of the routine or full-scale test, when it is required. The timeframe to perform maintenance and testing typically depends on factors such as the equipment to be serviced, complexity of the system, manpower and resources, outage time available, and mission constraints.

Full-scale maintenance and testing should follow NETA standards. Appendices E5 and E6 provide the NETA standards for maintenance and testing. Maintenance and testing should be performed by NETA or NICET certified technicians. The appropriate test equipment should be used by the certified professional to conduct maintenance or testing of energy systems or infrastructure. For example, the following are common testing equipment used: high-current test sets, high-resistance ohm meters, insulation testers (various), transformer turns ratio (TTR), and current transfer ratio (CTR) test equipment, 3-phase relay test sets, and tan-delta cable test sets (DC high-potential testing is not a sufficient substitute). When testing results are consolidated, they should be compared to the NETA acceptance test specification (ATS). Appendix E6 provides the NETA ATS values to help measure and identify potential equipment failure and to help plan for remediation.

Integrated System Test (IST)

ISTs are the most stringent of all testing requirements. ISTs have also been referred to as “Black Start Tests” or “Pull the Plug Tests”. A detailed example of an Integrated System Test (IST) documentation can be found in Appendix E7. In developing an IST, a clear understanding of the Tier Level System Topology (Appendix E8) and a set of updated control and schematic diagrams are essential.

ISTs ensure that the complete electrical and mechanical system will recover from a loss of power loss and voltage from the primary source and will, on the detection of this loss, immediately start automatically in an orderly manner. An IST not only tests the electrical and mechanical components of the system, but it also verifies that all control circuitry will function correctly. An automatic start after a power failure of the primary source will often cause control relays and logic to behave erratically, causing them to operate incorrectly or not operate at all. In most instances, control circuit failure is due to contact race or timer malfunction which results in start-up sequences being interrupted or not responding correctly.

ISTs require that the entire system be disconnected from its main power source by opening the main utility circuit breaker to simulate a loss of utility power/voltage. An IST should be performed when the system is first commissioned/put into operation, and then every year thereafter. Additionally, if modifications or additions have been made to control circuits, an IST should be scheduled when the modification was performed as part of the commissioning process to ensure that the system responds as expected in the event of a utility power failure. ISTs require proper planning to ensure that disruption to a base, campus, or facility is kept to a minimum and that a mitigation plan is in place in the event of a failure.

The following criteria and guidance should be considered when planning an IST:

- a) Start to plan an IST at least six months in advance (longer if the system is more complex).
- b) Ensure that all one line, schematic/control, and riser diagrams are updated and current.
- c) Make available all manufacturers operation and maintenance manuals.
- d) Include manufacturer’s personnel to be present at the test to ensure that should the equipment fail or not respond as intended, the account can be documented and corrected.
- e) Detail sufficient personnel to observe equipment and their response at various locations in the system.
- f) Maintain direct contact with all personnel and contractors through radio communications before, during, and after the test.
- g) Train personnel involved in the IST on the requirements for documenting their area of responsibility before, during, and after the blackstart.
- h) Have an approved mitigation plan in place should equipment fail or not respond appropriately. This will reduce down time in the event of an equipment failure.
- i) Have all emergency and security telephone numbers available. Communicate with management and leadership affected by the IST regularly. Include regular updates regarding IST status, progress, and timing. During the planning, training, and execution of the IST, include security POC, mission owners, tenant POCs, emergency recovery, response, life, and health & safety personnel. These parties should also be engaged on a regular basis regarding the status, progress, and timing of the IST.

As discussed, Appendices C and D provide example checklists to help manage, oversee, and record OM&T for energy resilient systems and infrastructure. Establishing the appropriate processes and procedures will be important to prioritize energy resilience decisions and gain organizational acceptance. The Services and Defense Agencies are encouraged to use this guidance to reduce energy resilience risks in the case of energy disruptions, and to ensure continuous power to critical mission operations on military installations, campuses, or at specific facilities.

Acronyms

AHJ – Authority Having Jurisdiction

ARMS – Arc flashing Reducing Maintenance Switches

ATS – Acceptable Test Specifications

BMC – Building Management Controls

CTR – Current Transfer Ratio

DASHO – Designated Agency Safety and Health Official

DCI – Defense Critical Infrastructure

DoD – Department of Defense

EOP – Electrical Operating Procedure

ESWP – Electrical Safe Work Practices

IAQ – Indoor Air Quality

IEEE – Institute of Electrical and Electronics Engineers

IST – Integrated System Test

MTS – Maintenance Testing Specifications

NEC – National Electric Code

NETA / IETA – International Electrical Testing Association

NFPA – National Fire Protection Association

NICET – National Institute for Certification in Engineering Technologies

OM&T – Operations, Maintenance, and Testing

OMETA – Operation, Maintenance, Engineering, Training, and Administration

OPC – Overcurrent Protective Coordination

OSHA – Occupational Safety and Health Administration

PE – Professional Engineer

PPE – Personal Protective Equipment

SCADA – Supervisory Control and Data Acquisition

SOP – Standard Operating Procedure

TTR – Transformer Turn Ratio

UP – Utility Privatization

Definitions

Arc Flash. An electric current that is passed through the air when insulation or isolation between electrified conductors is insufficient towards withstanding the applied voltage.

Authority Having Jurisdiction. An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Availability. The availability of an item – under combined aspects of its reliability, maintainability, and maintenance support – to perform its required function at a stated instant of time or over a stated period of time.

Critical Energy Requirements. Critical mission operations on military installations or facilities that require a continuous supply of energy in the event of an energy disruption or emergency.

Critical Infrastructure. Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.

Defense Critical Asset. An asset of such extraordinary importance to operations in peace, crisis, and war that its incapacitation or destruction would have a very serious, debilitating effect on the ability of the Department of Defense to fulfill its missions.

Emergency Systems. Legally required and classed as emergency by municipal, state, federal or other codes, or by any governmental agency having jurisdiction. These systems are intended to automatically supply illumination, power or both, to designated areas and equipment in the event of failure of the normal supply or in the event of accident to elements of a system intended to supply, distribute, and control power and illumination essential for safety to human life.

Installation Energy Resilience. The ability to prepare for and recover from energy disruptions that impact mission assurance on military installations.

Full-Scale System Testing. Operation of all associated emergency and standby energy generation systems, infrastructure, equipment and fuel at full operational loads while completely separated from the primary source of power.

Incident Energy. A measure of energy per unit area received within a working distance from an arc flash location.

Integrated System Test or Blackstart Test. The ability and process of restoring electrical power systems automatically in the event of a disruption utilizing on-site power generation independent from the local grid or transmission network to ensure that all systems return to their normal operation condition under abnormal conditions.

International Electrical Testing Association. An electrical testing standards developer for the American National Standards Institute that establishes standards, publishes specifications, and accredits independent, third-party, electrical testing companies, and certified testing technicians.

Inverters. Electrical devices used to convert Direct Current (DC) electric flows to Alternate Current (AC) electric flows. Many generation and battery or storage systems produce DC flows, while most electricity is consumed in AC. The inverter itself does not produce any electricity.

Lock-out. A safety procedure used to ensure that hazardous equipment is properly shut off and left off until maintenance or servicing work is completed. Also commonly referred to as a “tag-out.”

Mission Assurance. The process to protect or ensure the continued function and resilience of capabilities and assets – including personnel, equipment, facilities, networks, information and information systems, infrastructure, and supply chains – critical to the execution of DoD critical missions in any operating environment or condition.

National Institute for Certification in Engineering Technologies. A non-profit organization providing a nationally-recognized and acceptable procedure for recognition of qualified engineering technicians and technologists.

Personal Protective Equipment. Consists of protective items such as clothing, helmets, or goggles to minimize exposure to hazards that cause serious workplace injuries and illnesses.

Professional Engineer. A certification that ensures engineering professionals are held to the highest standard on behalf of the National Society of Professional Engineers.

Reliability. The ability of a component or system to perform required functions under stated conditions for a stated period of time.

Reverse power. A condition where the prime mover of a generator is not supplying sufficient torque to keep the generator rotor spinning at the same frequency as the grid to which the generator is connected.

Routine System Testing. Operation of all associated emergency energy generation systems, infrastructure, equipment, and fuel at full operational loads while still coupled with the primary source of power.

Standard Operating Procedures (SOPs). Step-by-step instructions to help workers carry out routine operations while achieving a degree of efficiency, quality output, and uniformity of performance.

Static bypass switches. Used to bypass uninterruptible power source normal operation in cases of high inrush or fault conditions.

Transfer switches. Electrical switches that changes a load between multiple sources.

Undervoltage. A condition where the applied voltage drops below 90% of intended levels for greater than one minute. Also commonly referred to as a “brownout.”

Zone Selective Interlocking. A method that allows multiple ground fault breakers to communicate to ensure a short circuit and/or ground fault will be cleared by the nearest breaker in as quickly as possible.

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