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DISTRIBUTION ENGINEERING DEPARTMENT
SYSTEM DESIGN SECTION

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TECHNICAL REQUIREMENTS FOR MICROGRID SYSTEMS INTERCONNECTED WITH THE CON EDISON DISTRIBUTION SYSTEM

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TARGET AUDIENCE	ELECTRIC OPERATIONS DISTRIBUTION ENGINEERING ENERGY SERVICES SYSTEM OPERATIONS REVENUE METERING
NESC REFERENCE	NONE

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TECHNICAL REQUIREMENTS FOR MICROGRID SYSTEMS

1.0 PURPOSE and SCOPE

The purpose of this document is to:

1.1 Describe the general technical requirements and considerations for interconnecting and operating a Microgrid system safely and effectively in the Con Edison Electrical Power System (hereinafter referred to as the EPS).

1.2 Identify the specific interconnection issues and technical requirements of a Microgrid interconnected with the EPS under the following conditions:

1.2.1 Operating the Microgrid system in parallel with the EPS.

1.2.2 Separating from and operating the Microgrid system in island mode when the EPS is lost or placed in a contingency condition, or in anticipation of a power system disturbance due to an inclement weather situation.

1.2.3 Putting the Microgrid system back to parallel operation with the EPS when service condition is restored normal.

2.0 APPLICATION

All Regions

3.0 DEFINITIONS

3.1 **Customer** and **Company** – in this document Consolidated Edison Company of New York, Inc. is referred to as the "Company." All reference to "Customers" shall refer to the entities receiving electrical power service from the Company.

3.2 **EPS** – in this document refers to the Con Edison electrical power system. The EPS includes the following Company systems:

3.2.1 **Network –** refers to the 120/208 Volt 3-phase 4-wire secondary network system. The secondary network system is a mesh of secondary voltage cables supplied by numerous but geographically-separated network units. The network units are banks of network transformers and associated network protectors supplied from the medium voltage (13/27/33 kV) primary distribution feeders. This system configuration is also referred to as an “area network” or “street network”.

3.2.2 **Spot Network** and **Isolated Network** – refers to a multibank installation, intended to serve a building or campus, consisting of two or more transformers that has the capability to sustain the loss of one feeder (1st contingency design) or two feeders (2nd contingency design), connected on the secondary by a bus or intervault ties, with or without a tie to the street network. Generally, an installation whose secondary bus does not have a [1]tie to the street network is referred to as an **Isolated Network.**

3.2.3 **Auto-Loop –** refers to the 13kV, 27kV, and 33 KV overhead radial automatic loop systems. The auto-loop is an open loop supplied normally by two feeders through automatic reclosers that operate to isolate a faulted section and minimize the number of customers interrupted due to a fault. (Refer to the Company specification EO-2067 for the design of various types of auto-loop systems - e.g. 2-Recloser Loop, 3-Recloser Loop, 5-Recloser Loop, or 7-Recloser Loop). The operation of the auto-loop system is described in EO-4119 and EO-4134.

3.3 **Distributed Energy Resources (DER)** – the small-scale power generation sources located at, and installed close to where electricity is used at the Customer’s facilities (e.g., home, data center, industrial complex, college campus, hospital campus, etc.). DER includes both generators and energy storage technologies capable of exporting power to the EPS.

3.4 **Distributed Energy Resources Operator (DER Operator): - The** entity responsible for designing, building, operating, and maintaining the DER.

3.5 **Primary Feeder –** refers to the high-tension primary distribution system consisting of 13/27/33 kV primary feeders that supply the secondary network system, the spot networks, and the auto-loop system. A Microgrid may be interconnected to the primary feeders via a High-Tension Service equipment that is designed, installed, and tested in accordance with Company specification EO-2022.

3.6 **Microgrid** – A group of interconnected loads and DER within clearly defined electrical boundaries that acts as a single controllable entity which can

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[1] Con Edison specification EO-4007 provides the definition and proper distinction of Spot Network and Isolated Network.

connect and disconnect from the surrounding utility grid or EPS and operate in both grid-connected or island mode.

3.7 **Microgrid Operator** – The entity responsible for operating, and maintaining the Microgrid system.

3.8 **Microgrid Tie Point** – The point or multiple points in the electrical system where the Microgrid system is interconnected with the EPS.

3.9 **Microgrid Interconnection Device (MID)** – A device installed at the Microgrid Tie Point(s) that allows separation of the Microgrid from the EPS. This device could be the network protector, a circuit breaker, or a disconnect switch.

3.10 **SIR** – the New York State Standardized Interconnection Requirements and Application Process for New Distributed Generators 5 MW or Less Connected in Parallel with Utility Distribution Systems

3.11 **SCADA** – Supervisory Control and Data Acquisition

3.12 **Microgrid Interconnection Agreement** – the site- and case-specific interconnection agreement signed by the Company and Microgrid developer covering the operation and maintenance the Microgrid.

4.0 GENERAL

The Microgrid may be established, owned, and operated by the Customer or by other entities. These are technical specifications applicable to customers or third-party owners of microgrids and there will be no further discussion of Company owned microgrids herein.

4.1 Customer Microgrid

4.1.1 A Customer-owned and -operated Microgrid would offer customers two main benefits: 1) assurance that energy supplies will be provided to sites deemed critical for public services or safety even during wide-scale outages or natural disasters; and 2) enhanced reliability and resilience for high-priority sites where outages can cause serious disruptions, risks, or financial costs. The Customer shall prepare and submit for review a detailed design of the Microgrid system. The design shall: depict the interconnection scheme; identify and indicate the Microgrid Tie Point/s, the Microgrid Interconnection Devices, the specific combination of generators and loads that are to be interconnected in each one of the Microgrid operating modes (stand-alone or grid-connected); specify the necessary protection, control, and monitoring equipment; and provide a detailed technical description of the design and operating features of the proposed Microgrid system.

4.1.2 The Company shall conduct a review of the Microgrid design. The review shall include engineering studies to evaluate the impact of the interconnection of the Microgrid to the Company EPS, determine the conditions for operating the Microgrid system, and to identify any additional equipment to be installed or upgrading work to be undertaken. The review process shall be in accordance with the SIR, and/or the Company specification EO-2115. If the interconnection is at HT Service, the interconnection scheme shall also be evaluated in accordance with Company specification EO-2022.

4.1.3 The equipment furnished and installed by the Customer, shall be in accordance with all applicable requirements of the latest (and most stringent) IEEE (ANSI), NEMA, National Electric Code (NEC), City Administration Code, DEP, EPA, OSHA and all applicable local codes and standards. Company requirements are in addition to and in no way a waiver of the applicable standards and codes. Where a difference between codes and Company requirements exists, the more stringent requirement shall be employed.

4.1.4 The interconnection requirements for DER's in the Microgrid are provided in the latest revision of Company specification EO-2115 and the SIR. Refer also to Section 13.0 (List of References) for additional information and guidance.

4.1.5 After the completion of the installation, the Customer must perform all acceptance testing on the installed interconnection electrical equipment as well as the operational tests and calibrations on the protective relays.

4.1.6 Final Inspection and Pre-Operational Checks – After the Customer announces installation completion, a mutually agreed upon time shall be scheduled for the inspection, and system pre-operational tests and trip checks that shall be witnessed by Company technical representatives. The Customer shall prepare a test plan that includes at a minimum the operation of the protection and control system, status indication, alarm and trip circuits, any mechanical, key, and electrical interlocks, telemetry, switchgear, and grounding devices. The Company representatives will be present for the above tests. A complete acceptance test report as well as the protective relay certification test report must be submitted to the Company for approval at least two weeks prior to completion.

4.1.7 System Hardening and Resiliency – Considering the increase in storms and flooding, the Company recommends that the Customer consider incorporating system hardening measures to improve the ability of the Microgrid to withstand the impact of storm and severe weather events and to recover more quickly and return rapidly to normal operations. Depending upon the Customer's location, i.e., whether the Microgrid will be located in a current or future floodplain, the design could include hardening features to improve the durability and stability of the Microgrid to operate as designed during severe weather events with minimal damage. Such features include, elevating equipment above the flood/surge plain, installing bulkheads and/or berms, waterproofing equipment entrances and apertures (e.g., vents, chases, etc.), installing isolation valves on drains, sealing/waterproofing all ducts and conduits to prevent water intrusion and installing emergency pumping facilities.

4.1.8 The interconnection and operation of the Customer Microgrid shall be covered in a site-specific Interconnection Agreement entered into by the Company and the Customer. The agreement shall include a site-specific Operation and Maintenance (O&M) specifications detailing the requirements, conditions, procedures, and responsibilities for operating and for transitioning the Microgrid to operate in stand-alone and grid-connected modes.

4.1.9 Customer Training

The Customer shall provide training to ensure that their qualified personnel have the knowledge and skills required to safely operate and maintain the Microgrid system. The Customer shall certify that employee training has been accomplished and is being kept up to date. The certification shall contain each employee's name and dates of training and the Customer shall produce this documentation on request by the Company.

5.0 OBJECTIVES AND TECHNICAL REQUIREMENTS

5.1 General Microgrid Interconnection design

The Microgrid, with its embedded DERs that interconnect and operate in parallel with the Company EPS, is a source of voltage and power and shall have adequate protection, control, and monitoring system to detect and prevent abnormal conditions in the Microgrid system and in the EPS. This is to insure that the Microgrid system will not affect the reliability and safety of the service provided by the Company to its customers in the Microgrid, and to the Company's other customers.

The system conditions that must be sensed by the Microgrid control and protection system include: short circuits, open circuits, abnormal voltage, abnormal frequency, out-of-phase reclosing, unintentional islanding, energization of a de-energized equipment or circuit, power quality issues, etc. The Microgrid shall be effectively isolated automatically from any faulted equipment or circuit so as to prevent damage and adverse impact to the EPS.

The protection and control requirements will depend on the configuration of the Microgrid, the ratings and characteristics of the generators and loads, the type of the EPS system, the operating scenario, the intertie location, etc.

The design of the Microgrid system, its basic configuration, operating characteristics, protection and control scheme, metering, SCADA system, automatic controller system, etc. will be reviewed by the Company technical representatives on a case-by-case basis. Every Microgrid system will be distinct and even similar systems connected at different locations with different types of service and operating scenarios could have different technical requirements. A site- and system-specific design specification, based on and following the general requirements of EO-2115, the SIR, and other applicable standards will be prepared and approved for each particular case.

5.2 Microgrid Operating Modes

The Microgrid can be operated under the following operating modes:

5.2.1 Parallel Mode - Normal grid-interconnected Mode (parallel operation) – in this mode the Microgrid is electrically interconnected with the EPS, generating power to fully or partially supply the loads within the Microgrid, including injection of power into the EPS. When interconnected in parallel with the EPS, the operating requirements of the latest edition of IEEE 1547, the Company specification EO-2115, and the SIR shall be followed.

5.2.2 Emergency Operation (islanded) – in case of failure of the EPS or in anticipation of a power system disturbance, the Microgrid can operate in an isolated mode supplying its pre-determined loads as an island.

5.2.2.1 The Microgrid shall have the ability to disconnect (and reconnect) from the EPS in a controlled way.

5.2.2.2 Once isolated, the Microgrid shall operate in accordance with the requirements of IEEE-1547, particularly when Company-owned equipment and assets are included in the islanded configuration of the Microgrid. The voltage shall be maintained in accordance with the Company service specification EO-2065. The frequency shall be maintained at a nominal 60Hz.

5.2.2.3 The Microgrid shall have the capability to clear and/or isolate faults in the islanded system. In islanded mode, the short circuit levels would be reduced, and as a result circuit fuses and limiters may not blow and the faults could persist, and remain undetected. Special protection system must use adaptive protection schemes that would automatically change or adjust the settings of protective relays to become more sensitive to the reduced short circuit levels. Otherwise, the Islanded microgrid may be rendered inoperable if and when faults still remain to be located, cleared, and isolated.

5.2.2.4 The operation of the islanded Microgrid shall in no way impact the Company’s ability to restore service to its Customers not part of the islanded Microgrid.

5.2.3 The transition between Grid-connected and islanded modes shall be performed in a controlled manner.

5.2.4 A detailed site- and system-specific Operation and Maintenance Specification shall govern the process of operating the Microgrid in parallel with the EPS, in isolated mode, and its transitioning from EPS-connected to isolated mode and back.

5.3 Safety

The safety of the general public, and the personnel and equipment of the Company, shall in no way be reduced or impaired as a result of the interconnection and operation of the Microgrid system.

The Microgrid shall be designed and be equipped with appropriate protective and control functions that will prevent any DER in the Microgrid system from being connected to a de-energized circuit in the EPS. The protection and control system shall at all times ensure that proper voltage, frequency and phase angle exists between the EPS and the Microgrid before parallel operation is permitted.

It is important that any DER unit/s in the Microgrid trips out in the event of an EPS power outage to avoid a situation known as “unintentional islanding. The probability of unintentional islanding and the risks associated with the formation of an island extending beyond the boundary of the Microgrid shall be reduced.

The Company EPS operators shall be provided with the capability to remotely view the status of the Microgrid, even the ability to shut it down if necessary when an abnormal condition occurs such as: unintentional islanding, loss of synchronism, abnormal conditions of voltage, power flow, or frequency at the Intertie points or in any section of the Microgrid or in the surrounding EPS, etc.

5.4 *EPS System Impact* - The interconnection and parallel operation of the Microgrid with the EPS shall not:

5.4.1 Cause damage to the primary feeder cables and/or secondary main cables as a result of power or current flows exceeding the ratings of the cables.

5.4.2 Blow open cable limiters and circuit fuses as a result of abnormal or excessive power or current flows.

5.4.3 Result in the fault current interrupting and withstand capability ratings of equipment and circuits in any part of the EPS to be exceeded.

5.4.4 Result in any of the following issues to Network Protectors (NWP):

5.4.4.1 Exceed its fault-interrupting capability.

5.4.4.2 Cause any NWP to connect two dynamic systems together.

5.4.4.3 Cause any NWP to operate more frequently than prior to the parallel interconnection of the Microgrid.

5.4.4.4 Cause any abnormal cycling of NWP.

5.4.4.5 Prevent or delay the NWP from opening for faults on the network feeders.

5.4.4.6 Delay or prevent NWP closure.

5.4.4.7 Require the standard Company NWP settings to be adjusted, except on special cases.

5.4.5 Energize a de-energized network.

5.4.6 Interfere with the normal operation of the autoloop system, reclosers, radial systems supplied from ATS's, etc.

5.4.7 Shall not cause an alive-on-backfeed condition on an unfaulted primary distribution feeder whose breaker has opened at the area station.

5.5 *Customer Impact* - The quality, reliability and the availability of service to the Company's other Customers shall not be diminished or impaired as a result of the interconnection of the Microgrid system.

5.6 *IEEE 1547 Compliance* - When in grid-connected mode, the DER units interconnected within the Microgrid shall comply with the requirements of the most updated edition of IEEE 1547 standard.

5.7 Short Circuit Protection

5.7.1 The Microgrid shall have the capability to be isolated from external faults (i.e. faults outside of the Microgrid boundary).

5.7.2 The Microgrid shall have the capability to clear internal (within the Microgrid system) faults in both parallel (EPS-connected) and islanded operations.

5.7.3 The overcurrent protection devices in the Microgrid shall be capable of being adjusted automatically to adapt dynamically to the change in short circuit levels as the Microgrid transitions between EPS-connected and stand-alone operations.

5.7.4 The fault current contribution of any distributed generation (DER) in the Microgrid to the EPS must be considered. In some areas of the EPS, the margin between the ratings of the protective equipment and the calculated fault current may be too narrow, precluding the installation of additional generation. The short circuit withstand and interrupting rating of equipment in the EPS shall not be exceeded. Where the fault duty limit has been reached, alternate methods of interconnection and must be explored and additional fault-current mitigating measures must be taken. These methods and measures may include:

- Reduction of total aggregate synchronous generation at the site so as to reduce the short-circuit current to an acceptable level.
- Use of alternative generation strategies, such as induction generators, and electric conversion equipment - e.g. AC-DC-AC converters, DC Link, etc.

- Use of fast-acting current limiting protective devices similar to G&W CliP, ABB IR limiter, etc. which can rapidly trip the generator to clear the fault in sub-cycle time.

5.7.5 The EPS is a stiff source that supplies a significant fault current contribution. When the Microgrid separates from the EPS and is placed in stand-alone operation, the stiff source is removed and the fault current is reduced to a level that may no longer be sufficient to operate protective devices such as current limiters, fuses, or protective relays. Inverted-based generators and storage systems can be particularly weak fault current sources, which may make some faults difficult to detect. The Microgrid supplied by weak fault sources may require special overcurrent detection and protection schemes.

While faults may be detected and cleared, most likely by undervoltage relays due to ensuing undervoltage condition, locating the faults could be difficult. The Microgrid system may be rendered inoperable and unable to supply the critical or essential loads it is intended to serve, until the fault is located, isolated, and corrected.

Note : [2]Synchronous generators may not be dispatched when the Microgrid is interconnected and operating in parallel with the secondary network (“Network”).

5.8 *Synchronization.* The Microgrid shall have provisions for synchronizing in one or more of the following methods at the Microgrid Tie Points.

5.8.1 *Active synchronization*—If the Microgrid voltage and frequency can be controlled sufficiently, then the Microgrid controller can align the voltage and frequency to the EPS and then close the circuit breaker. The auto-synchronizer function in the controller shall be set to the synchronization parameter limits in IEEE 1547 (see Section 7.6)

5.8.2 *Sync-check* — Reconnection shall be blocked by a sync-check relay (device 25) if the voltage and frequency of the two systems (EPS and MiroGrid) are not within the synchronizing tolerances. The Microgrid controller can initiate reclose of the Microgrid Interconnection Devices (MID), when the proper synchronizing conditions are satisfied in accordance with the synchronization

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[2] Subject to review and approval by the Company, special protection and control schemes may be utilized to allow the interconnection and parallel operation of synchronous generators with the Network System.

parameter limits in IEEE 1547 (see Section 7.6).

5.8.3 *Open Transition*— Involves de-energizing all DER units in the Microgrid, and then closing the MID to reconnect to the EPS. Once reconnected, the DER's can then be restarted as desired. This is the simplest option for reconnecting the Microgrid back to the EPS, but the repercussions of interrupting the loads should be considered.

5.9 Voltage and Power Control.

When interconnected in parallel with the EPS, the real and reactive power supplied by the generators should closely match that of the loads, and not cause the EPS voltage to go outside the requirements of ANSI C84.1-1995 Range A,

5.10 Dispatch

Dispatch for Microgrid survivability includes, but is not limited to:

5.10.1 While grid-connected, ensuring sufficient resources (e.g. generation and/or energy storage) are operating and available to support the Microgrid's transition to island mode.

5.10.2 While islanded, managing energy resources consistent with ensuring service to the Microgrid critical loads for the duration of the islanded state.

Dispatch for economic operation may include, but is not limited to:

5.10.3 Optimization of the Microgrid's energy consumption and generation against electric and natural gas tariffs.

5.10.4 Provision of services as applicable to the Grid, such as: energy, Volt/VAR support, frequency regulation, spinning reserve, black start support, demand response, etc.

5.10.5 Dispatch for environmental performance includes reducing or limiting CO2 emissions in accordance with standards.

5.11 Metering

The Microgrid shall have appropriate and adequate revenue-grade metering equipment for measurement of reactive and active power and energy, time interval data, and other metering data as required for compensation or remuneration of services provided by the Microgrid.

5.11.1 At the Microgrid Tie Points to account for interchange of power and energy between the EPS and the Microgrid when in parallel and in island mode

5.11.2 At the DER interconnection points for individually metering the power and energy of the DER installation.

5.11.3 At load service points for individually metering the entities participating in the Microgrid when in parallel and in island mode.

5.12 Black Starting.

The Microgrid shall have the capability to start its DER units from the de-energized state. The generation can be brought online first, then the load can be energized in steps or all at once, depending on the capabilities of the generators and the load characteristics.

6.0 STANDARDS AND CODE REQUIREMENTS

The Microgrid, the DER, and the associated interconnection equipment in the Microgrid, must be designed, installed, tested, and operated in accordance with the requirements of the latest, and most stringent, government, industry, and Company standards not limited to the IEEE (ANSI), NEMA, National Electric Code (NEC), National Electric Safety Code (NESC), City Administrative Code, DEP, EPA, OSHA and all applicable local codes and all authorities having jurisdiction. The Company requirements stipulated in EO-2115 and in other related company specifications are in addition to, and will not waive any of, the applicable standards and codes. Where a difference between codes and Company requirements exists, the more stringent requirement shall apply.

7.0 COMPONENTS OF THE MICROGRID SYSTEM

The Microgrid system would consist of the following basic components:

7.1 Generating Sources

The Microgrid must contain distributed generation (DER) in order to operate in island-mode. The generators generally fall under the following categories:

7.1.1 Emergency generators - utilized solely during power outages to supply power to highly critical and essential electrical loads. Accordingly, emergency generators rarely run. Diesel generators are the most common emergency power generation source. They have the ability to ramp up to full power and respond to varying demands within a few seconds. They can start and run completely unattended.

These generators shall have black start capability

Emergency generators may be deployed to the Microgrid but may require reconfiguring their output connections as these generators are typically wired via automatic transfer switches (ATS) to the building's emergency load boards.

7.1.2 Base load generators – are designed to run frequently or continuously, typically only shutting down for maintenance. They are designed to be operated in both parallel (EPS-connected) and stand-alone modes. They tend to be more expensive but more durable than emergency generators. Some DER base load units use conventional natural gas-burning reciprocating engines, gas turbines, micro-steam turbines, etc., and designed to operate as combined heat and power (CHP) systems to provide heating and/or cooling for buildings or for industrial processes, using the "waste" heat energy derived from electricity generation.

7.1.3 Intermittent generators - includes many renewable sources such as solar PV's and wind turbines. Intermittent generation may not provide adequately reliable generation capacity when the Microgrid is in island-mode.

7.1.4 Energy Storage System – batteries, and other energy storage systems that can convert electrical energy from the EPS or from intermittent generators within the Microgrid into a form that can be stored back to electrical energy when needed and can be used to support the Microgrid and optimize the balance between demand and generation.

The Microgrid should not rely exclusively on renewable energy resources as it may not provide electric power during grid outages with the level of reliability required for emergency loads. A synchronous generator and/or DC-AC power converter units of sufficient rating may be needed to provide the stiff base for the islanded Microgrid system. These shall be relatively fast responding controllable sources, with the capability to maintain the Microgrid system voltage and frequency, to supply the reactive power (kVAR) requirements of the system and of induction generators (if any), and to provide the voltage reference for commutation of dc-ac power converter-based generators that may be included in the mix of DER's in the Microgrid. Typically, a synchronous generator, powered by a diesel or natural gas engine would be the reliable 24 x 7 source that would supplement the renewable energy generators in the Microgrid.

All the synchronous generators that participate in the Microgrid's "shared" distributed generation shall be capable of parallel control, PF control, voltage matching, speed control, load ramping, and have the required protective relaying per IEEE 1547. These requirements are not necessarily for synchronous generators intended to be run for emergency, standby, or legally required source on a customer's isolated load bus.

It is assumed that some of the generation capacity installed in the different entities will be “shared” with other facilities via the common Interconnection bus provided by Con Edison’s 208/120-Volt secondary network.

7.2 Load Switching System

Where the aggregate generation capacity in the Microgrid is not adequate to supply the entire load, the loads will need to be segregated based on priority, and critical and non-critical loads pre-determined. The switchboards for these loads would have smart switches or breakers connected to a SCADA system (or other similar systems) for remote control (trip and close), load monitoring (kW, kVAR, amps, volts, etc.) and status monitoring of switches and/or circuit breakers. When the Microgrid is in island operation, the loads can be selectively switched on or off according to their assigned priority, in order to keep the load dynamically matched to the current generation capability.

7.3 Boundaries and Method of Isolation

Forming the Microgrid will start with determining and selecting its geographical and electrical boundaries. The engineering, economic, and commercial logistics of identifying these boundaries will need a process not described in, and out of the scope of this specification.

Secondary Network System (“Network”)

Carving out the Microgrid from its surrounding Network will require:

7.3.1 Cutting selected secondary main conductors and installing electrically operated isolation switches or circuit breakers in-line with those mains.

Only one (1) of the inline disconnects needs to be a 3-pole electrically operated and controlled circuit breaker. The significance of this tie point and why it needs to be a circuit breaker is explained in *Section 14.3 (Transitioning the Microgrid from island mode back to parallel mode)* describing the closed transition retransfer from island back to grid connect mode.

7.3.2 Network protectors (NWPs) within the Microgrid’s boundary shall be placed in the blocked open position. For safety and expediency, it may be necessary to equip the NWP’s with the ability to be operated and locked-open with a remote control system.

7.3.3 The Microgrid Interconnection Devices (MID) at the Microgrid Tie Points, whose quantity will depend on the number of tie points, may be fulfilled either by circuit breakers or switches. All MID’s, including NWP's will be required to be open during Island mode. Conversely, if any one MID device is closed, the Microgrid shall still be considered as being in "grid-connected" or "paralleled" mode.

The switches and circuit breaker shall have the following features:

- Electrically operated close and open, remote and local control, accepting of a DC source for control power and data communication.
- SCADA monitoring of position and tripped status
- Capability for remote closing and opening via SCADA or other controller system.
- SCADA monitoring of analog electrical quantities – kW, kVAR. Amps, Volts, etc.
- Sync-check relay (ANSI device "25") with live-line and live-bus indication via LED or meter display.
- Circuit breakers shall have overcurrent protection, using either their integral trip unit or external relays, for fault and overload clearing with trip indication.
- The circuit breakers shall be capable of fault-interruption up to the calculated 3-phase short circuit level.
- The switches shall have load-interrupting capability.
- Switches shall have a visible contact break with a grounding position. Breakers whose contacts are not visible shall be draw-out type or equipped with a switch in tandem to provide the visible break isolation. Refer to NESC.

7.3.4 Network Protectors (NWP)

The network protector that interconnects the primary distribution system and the secondary grid is designed to prevent power flow from the secondary to the primary grid. They are designed to trip on reverse power and will re-close if the system condition it senses indicates the necessity. Due its slow operation, out-of-phase reclosure can occur.

7.3.4.1 The DERs in the Microgrid can interfere with the reclosing scheme by offsetting the network load to a point at which an open network protector cannot reclose because the network voltage or phase angle is outside the permissive closing boundary. Modifying the relay reclosing settings to accommodate the DER may lead to more frequent network protector openings under light load conditions and shall be avoided.

7.3.4.2 The DER sources in the Microgrid can cause inadvertent islanding to occur if NWP's trip on reverse power from the DER.

7.3.4.3 Control Power - network protectors (NWP) obtain the control power source from the line or transformer-side of the circuit breaker. Under a total network outage, an auxiliary control power source may be required for network protectors that stayed closed to be remotely tripped via SCADA or the Microgrid Controller System. Safety interlocks shall be provided to effectively remove the auxiliary power source once the NWP is put back to its normal operating status.

7.3.4.4 The network protector shall have:

- Microprocessor network protector relays with communication capability.
- SCADA capability for status monitoring and remote control opening and blocking in open position, and close prevention
- SCADA capability for monitoring of analog quantities – kW, kVAR. Amps, Volts, network transformer temperature, etc.

Auto-Loop System

7.3.5 The Microgrid shall have a single Microgrid Tie Point with the auto-loop system. Where more than Microgrid Tie Point is necessary, only one point shall be active at any one time.

7.3.6 A circuit breaker shall be used as the **Microgrid Interconnection Device (MID)** for connecting to and isolating the Microgrid from the auto loop.

The circuit breaker and the interconnection equipment or switchgear, shall comply with the requirements of Con Edison specification EO-2022, and shall be designed, manufactured, installed and tested in accordance with the latest applicable industry standards, including ANSI, IEEE, NEC, NESC, OSHA, UL, NEMA and any applicable local or city rules, regulations or ordinance codes.

Primary Feeder System

7.3.7 A Microgrid interconnected to the Primary Feeder system shall utilize High-Tension Service equipment designed and installed in accordance with the requirements of Company specification EO-2022. The primary and secondary main breakers shall be considered as the Microgrid Interconnection Devices (MID).

7.4 Master Microgrid Controller (MMC) system

The MMC is an intelligent system designed to manage and automate the operation of the Microgrid system. The MMC shall have the capability to monitor, control, and obtain dynamic feedback from all the different entity facilities participating in the Microgrid.

The MMC shall have the following specific functions and features:

7.4.1 Monitors the status of the network protectors, breakers, switches, and MID's used to interconnect the Microgrid system to an EPS system.

7.4.2 Open and block open the network protectors. When this is not possible, Company personnel shall manually open and block open the network protectors,

7.4.3 Actively controls the synchronization of the Microgrid's paralleled generation to the EPS when returning from island mode to normal grid connection. When proper synchronization is confirmed at the Microgrid Tie Points, will send the closing signal to the proper MID.

7.4.4 Monitors and logs the interchange of the power and energy at the Microgrid Tie Points.

7.4.5 Controls the selective switching of non-critical loads based on predetermined and assigned priorities.

7.4.6 Acts as the generation control sub-system to control and manage the following tasks in Island mode:

7.4.6.1 Maintaining the optimum total online generation capacity by dynamically matching the Microgrid's total load with the quantity of paralleled generators.

7.4.6.2 Automatic start-up and shutdown of generating units using a prioritized scheme based on runtime hours and engine size.

7.4.6.3 Bringing offline generators back online when critical or non-critical alarms are received from online generators.

7.4.6.4 Regulation of the individual generators' loading and load sharing.

7.4.6.5 Automatic isolation of the Microgrid in the event of total EPS brownout or blackout. Start-up and initial loading of blackstart-capable generators is still in the hands of individual entities' control systems before the MMC can synchronize and combine them into a paralleled DER bus.

7.4.6.6 Control and regulation of the system frequency, voltage, and load sharing of the generators (both kW and kVAR) when the Microgrid is in island mode.

7.4.6.7 Real-time measurement and control of the generation and consumption of real and reactive power in the Microgrid while in grid connection mode. If exporting power to the rest of the EPS, the MMC must maintain the kW, kVAR, and PF export setpoint across the Microgrid tie point(s).

7.4.6.8 System time-keeping to make sure that the system frequency averages to 60.00 Hz in the long run.

7.4.7 MMC control power

The MMC shall have a dual power supply system rated and specified to be fed from an uninterruptible power supply (UPS).

7.4.8 MMC memory

The MMC shall use non-volatile memory to ensure that the system can cold start following complete loss of its power supply.

7.5 Protective Relaying

The Microgrid shall have a protective relaying scheme for protecting both the larger surrounding EPS and the Microgrid system from faults, and from abnormal voltage and frequency conditions. The protective relays shall be utility-grade and shall have the required protection functions (e.g. 27, 59, 81u, 81o, 50/51, etc.) as prescribed in the latest edition of IEEE 1547 standard.

The protection devices in the Microgrid shall have multiple setting groups and be capable of being set automatically to adapt dynamically to the change in the system configuration and short circuit levels as the Microgrid transitions between grid-connected and stand-alone operations.

7.6 Synchronizing Equipment

The transition from the island mode to parallel operation with the EPS, and in particular closed-transition or seamless transfer will require synchronizing equipment necessary to supervise the closing of the Microgrid Interconnection Devices (circuit breakers or circuit switchers).

The table below specifies the synchronizing parameters for interconnecting the Microgrid to the EPS.

Synchronization thresholds for distributed generators based on IEEE 1547-2003			
Parameters	AGGREGATE GENERATOR SIZE (KVA)		
	0- 500	500 - 1500	1500-10,000
Voltage Difference (Δv) - %	10	5	3
Frequency Difference (Δf) - Hz	0.3	0.2	0.1
Phase Angle Difference (Δθ) - degrees	20	15	10

All intertie-point circuit breakers shall be equipped with synchronizing check-relays that are set in accordance with the requirements as shown in the table above, regardless of whether the breaker is selected to be the first one to close in the transfer switching.

7.7 Metering and SCADA Equipment

The Microgrid shall have Metering and SCADA equipment for real-time monitoring of analog and discrete data points on a human machine interface (HMI), and for obtaining historical data trending of metered values, and alarm/event logging. Controls and visibility shall be available at a Microgrid control room, and on remote consoles having secure access.

The visibility shall be extended to the Company EPS operators. The data points to be monitored shall include the status of the MIDs, circuit breakers and disconnect switches, the kW, kVAR, voltage, and current at the Microgrid Tie Points and at individual DER connection point as necessary.

7.8 Microgrid system security

The Microgrid system shall be safeguarded from physical and cyber attack by means of a well-defined security policy and procedure.

8.0 MICROGRID OPERATING ISSUES IN THE SECONDARY “NETWORK” SYSTEM

The standard electric service in the Con Edison service territory is a 120/208-Volt secondary network system or “Network”. The Network is designed so that each low-tension service load receives its power and energy from several transformers that are simultaneously supplied from several high tension (13.2, 26.4, or 33 kV) primary feeders. The Network is formed from the interconnection of the secondary windings of these transformers in a parallel configuration.

A unique feature of any Network system, compared to a radial distribution system, is the addition of the Network Protector (NWP). The NWP is a relay and breaker combination that senses reverse-power flow through a transformer toward the high tension feeder. The reverse power comes from other paralleled transformers that are backfeeding into the feeder after feeder clearance due to a fault, or a planned outage. The NWP is designed to interrupt the reverse power flow by opening the breaker. The network protector’s opening ensures isolation of a feeder for repair. It also is an important component for service reliability by preventing a cascade of feeder outages, which could occur if a faulted feeder continued to get backfed by other transformers in the secondary network. The ability of the NWP to be manually opened (remote or local control) allows for continuous secondary network uptime while one or more feeders are safely de-energized for planned maintenance.

The NWP relay has reverse power function (32) that can be set as low as the magnetization power of its associated transformer or as high as what can be caused by a fault on the feeder or in the transformer itself. The NWP will also reclose the breaker when the voltage and phase of the primary feeder are such that power will flow into the area network after the breaker closes. It is also designed to recognize a cross-phase condition (caused by a feeder re-splicing mistake), which prevents the breaker from closing.

The very sensitive reverse-power pickup of the network protector relay is a major concern in the application of DERs on secondary networks. Power export from a DER intertie that is not absorbed by loads in the immediate Network area can open network protectors if they backfeed for 6 cycles (0.1 seconds) or more. DER’s that are exporting can inadvertently create an island condition if they cause the opening of enough network protectors in the vicinity, either as a result of reverse power or overload trip of those remaining connected.

The DER on a secondary network system can interfere with the NWP reclosing scheme by offsetting the Network load to a point at which an open NWP cannot reclose because the network voltage or phase angle is outside the permissive closing boundary. Modifying the relay reclosing settings to accommodate the

DER may lead to more frequent network protector openings under light load conditions and shall be avoided.

9.0 MICROGRID OPERATION IN THE SECONDARY “NETWORK” SYSTEM

9.1 APPENDIX A in Section 14.0 describes the operation of a typical Microgrid System in the secondary Network system. The information contained therein is general and not intended to cover all details and aspects of a particular case.

9.2 Because every Microgrid system can have specific requirements, a site- and system-specific Operating and Maintenance specification shall be prepared for each particular case.

10.0 MICROGRID OPERATING ISSUES IN THE OVERHEAD AUTO-LOOP SYSTEM

10.1 Service Reliability

The overhead feeders in the auto-loop system, including 4 kV system, and radial loads fed off ATS’s are prone to faults. The DERs interconnected with the auto-loop will be subjected to the interruptions. The DERs must be disconnected, even momentarily, when the auto-loop goes into its sequenced switching operations in the process of clearing a fault and isolated the faulted section.

10.1 Recloser Operation Interference, Unintentional Islanding, and Out-of-Sync Reclosing

10.1.1 Recloser Operation Interference - Reclosers depend on the voltage that they sense at their point of connection in the autoloop for its operation. The Microgrid system can maintain voltage in the autoloop, thus interfere with the operation of the reclosers.

Taking for an example the auto-loop system shown in Figure 1, if a permanent fault occurs at point A on the source side of recloser FR, the feeder recloser will normally open on loss of potential after the station breaker opens. However, if a Microgrid system is connected and operating in parallel in that section, voltage can persist in Section B preventing FR from sensing a loss of potential thereby failing to open. TR will also not close for as long as voltage is sensed from Section B. Thus Section B can be energized as an “islanded system” until the Microgrid trips out or gets disconnected from the auto loop.

10.1.2 Out-of-Sync Reclosing - The Microgrid shall have dead-line sensing to ensure that the Microgrid and/or the DERs in the Microgrid is disconnected in less than the dead time in order to avoid out-of-phase reclosing or accidental islanding, which could damage the Company's equipment as well as the Company's other customers' equipment.

The Microgrid intertie breaker shall trip and isolate the Microgrid off a faulted section of the auto-loop system before the reclosing operation takes place. To prevent any recloser from closing out-of-sync into a section of the auto-loop that could still be energized from the Microgrid, a fast transfer trip system shall be required.

When the associated recloser (FR and/or MR) trips, a transfer trip signal shall be sent to automatically trip and lockout the Microgrid intertie breaker until the recloser's trip and reclose sequence is completed and the fault cleared.

The reclosing dead time of reclosers may be adjusted to up to 5 seconds, to provide a safe window for synchronous DERs in the Microgrid system to be disconnected and isolated.

The Microgrid Intertie Circuit Breaker shall be prevented from closing into a de-energized EPS.

10.1.3 Unintentional islanding operation shall be prevented to occur. Any or all of the following anti-islanding schemes may be implemented:

10.1.3.1 Passive anti-islanding methods using local protective relays that measures and detects the deviation of the frequency, active and reactive power, voltage, even the rate of change in the frequency, from the normal operating range.

10.1.3.2 Communication–based transfer trip schemes

10.1.3.3 Sizing the DER appropriately so that there is essentially no chance that they maintain an island for any period of time

10.1.3.4 Special protective schemes that include synchrophasor comparison, etc.

10.2 Short Circuit Current Levels – The short circuit contribution from the Microgrid generating source can cause the short circuit level on any section of the auto-loop system to exceed the rating of the reclosers, sectionalizing switches, fuses, etc. In such a case, mitigating measures must be taken to ensure that the short circuit limit is not exceeded. Some of these measures include:

10.2.1 Reduction of total aggregate generation at the site to an acceptable level.

10.2.2 Use alternative generation strategies, such as induction or DC inverted generators.

10.2.3 Use of AC-DC-AC converters, and/or a “DC Link” product, whose electric conversion and interface equipment would also minimize the generator’s fault current contribution.

10.2.4 Use of electronically-triggered fast acting current limiting fuses (e.g. “CliP”, “Is-Limiter”, etc.) which acts to rapidly trip the customer’s generator effectively limiting the fault energy that would otherwise be normally released and injected into the system.

10.3 Short circuit Levels during Microgrid Stand-Alone or Islanded Operation

The utility is a stiff source that supplies a significant fault current contribution. When the Microgrid is placed in stand-alone operation, the stiff source is removed and the fault current is reduced to a level that may no longer be sufficient to operate protective devices such as overcurrent relays or fuses. Inverted-based generators and storage systems can be particularly weak fault current sources. While faults may be detected, for example by undervoltage relays, fault locating can be troublesome. The entire Microgrid or a significant portion of it may be rendered inoperable and unable to supply critical or essential loads until the fault is located and corrected.

10.4 Effective Grounding

An island with line-to-neutral connected loads should be effectively grounded. Effective grounding is essential for limiting over-voltages on the un-faulted phases and keeping line-to-ground fault currents sufficient to operate overcurrent protective devices. Transformer connections and generator grounding should be reviewed to ensure that an effective grounding is established. If a line-to-ground fault occurs when islanding and the islanded Microgrid is not effectively grounded, loads connected line-to-ground may see voltages above 1.8 per unit.

If the effective grounding is lost when the Microgrid is reconfigured for stand-alone operation, grounding transformers or other means shall be provided to effectively ground the system.

10.5 Open circuit Conditions

An open circuit on the open wire portion will result in one of the following operations:

10.5.1 An open circuit on one or two phases may cause a phase unbalance large enough to trip the station breaker. On the other hand, the operation of a Microgrid system in the auto-loop can also mask the phase unbalance condition and remain undetected.

10.5.2 The Microgrid may experience unnecessary interruption outage resulting from open-phase conditions in the auto-loop.

To avoid the above-cited issues the Microgrid should be interconnected to the solid main runs, and not on branch circuits that are protected by branch fuses.

10.6 Voltage variations in the auto-loop

The Microgrid shall control its reactive and active power so as not to cause the loads in the auto-loop experience voltages outside of the requirements of ANSI C84.1-1995 Range A.

11.0 MICROGRID OPERATION IN THE AUTO-LOOP SYSTEM

11.1 APPENDIX B in Section 14.0 describes the operation of a typical Microgrid System in the Auto-Loop system. The information contained therein is general and not intended to cover all details and aspects of a particular case.

11.2 Because every Microgrid system can have specific requirements, a site- and system-specific Operating and Maintenance Specification shall be written and approved for each particular case.

12.0 MICROGRID OPERATING ISSUES IN THE PRIMARY FEEDER SYSTEM

The interconnection of a Microgrid system that includes DER generators ranging in size from in size from 2 to 20 MW, are required to interconnect at High Tension (HT) voltage levels using HT Service equipment that meets the requirements of specification **EO-2022.**

The Microgrid may be operated to export power to the primary feeder EPS if the on-site generation exceeds on-site demand or is designed to supply electricity from the DER units through the high-tension system to multiple low-tension or high-tension service accounts on the premises under the offset tariff. In the standard HT Service bus-breaker configurations in Company specification EO-2022, the primary breakers as well as the secondary main breakers are considered to be the Microgrid Interconnection Devices (MID).

12.1 Feeder Alive-on-Backfeed (ABF) Condition

The Microgrid shall be able to detect and clear a feeder ABF condition. An ABF condition can occur if the primary and/or secondary breaker at the Microgrid HT Service facility fails to trip open after the substation feeder breaker opens. This is particularly of concern for a Microgrid system exporting power to the primary feeder system where the reverse power relays (32) on the secondary main breakers are de-activated to allow power export.

A communication-based transfer trip system shall be employed to ensure that the corresponding primary and secondary breaker at the Microgrid HT Service facility trips after the substation feeder breaker opens.

12.2 Islanding Condition

The Microgrid shall be able to detect an unintentional island and cease to energize the primary system EPS in accordance with the requirement IEEE 1547.

Any or a combination of the following schemes can be employed to address this issue:

12.2.1 Local detection schemes

- Frequency-based – uses locally measured frequency to sense if an island has formed. If an island does occur, the local frequency will drift depending on the power mismatch between the Microgrid generation and the resulting total load of the island. Excess generation will drive up the frequency and deficit generation will result in decreasing the frequency. Frequency relays may be set to trip when the frequency and/or rate-of-change of frequency go above or below the set points.
- Voltage-based – uses the locally measured voltage to sense if an island is formed. If there is a mismatch in the reactive power from the DERs and the requirement of the resulting load, the voltage will shift outside the preset limits of the relay voltage protective function to initiate a trip. .
- Vector Surge – the vector surge relay measure the phase angle shift of the voltage waveform with respect to a locally generated reference waveform
- Other passive schemes – e.g., change of power output, change of reactive power output, power factor (P/Q) and df/dp indices.

12.2.2 Communication-based Transfer Trip System

12.2.3 Synchrophasor comparison – detects the difference and/or rate of

change of the angle and/or frequency between the reference voltage in the EPS (obtained from the secondary network system "Network," or the substation) and the locally measured voltage in the Microgrid using synchrophasors based on IEEE C37.118

12.2.4 Active islanding schemes and other evolving methods. These shall be reviewed on a case-to-case basis.

13.0 LIST OF REFERENCES

The following references are given for guidance and information of Microgrid system developers.

Reference Number	**Title**
EO-2115	Handbook of General Requirement for Electrical Service to Dispersed Generation Customers
IEEE 1547-2003	Standard for Interconnecting Distributed Resources with Electric Power Systems
IEEE 1547.4-2011	IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE P2030.7	Standard for the Specification of Microgrid Controllers
IEEE P2030.8	Standard for the Testing of Microgrid Controllers
NYS-SIR	New York State Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems

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14.0 APPENDIX A

Operation of a typical Microgrid System in the secondary Network

14.1 EPS-Connected Operation

The Microgrid with its embedded DER's can be successfully interconnected and operated in parallel with the Network by following the guidelines and requirements of the NY State Standard Interconnection Requirements (SIR) and the Con Edison specification EO-2115.

Synchronous generators are NOT approved for connection to the Con Edison secondary networks unless they are online for the purpose of islanding the Microgrid, or fall into an exception agreement for special conditions.

In general, the approaches for interconnecting with the Network are:

- DER without Net Metering:

  Maintain the aggregate generating capacity of the DER's smaller than the minimum load at the customer meter. The system shall be designed to ensure that the site load is always drawing some power from the Company grid with essentially no chance of exporting energy from the DER system into the Network.

  - Provide a front-end reverse power relay (ANSI device 32) and configure it for under-power sensing to ensure that the facility will draw a minimum import power from the secondary grid at all times. The reverse power relay shall be made to disconnect generators, outright or in sequential order, if the incoming power flow from the secondary network drops below a pre-determined threshold. A second setting on the 32 relay may be used to allow a momentary export for a short time to allow the DER's to ride through incidental reverse power, such as the surge of reverse power caused by regenerative braking action of elevators.

    In addition to the 32 relay, a dynamic load-following control system shall be provided that monitors in real-time the level of power across the intertie point and regulates the DER output to stay below the reverse power trip level with a safety margin. This is a more desirable solution to prevent the DER units from reaching the reverse power relay (32) trip level, and avoid the unnecessary disconnection of the DER.

- DER with Net Metering:

DER facilities eligible for Net Metering may have limited opportunity to export into the Network. To permit power export, the NWP relays are set to insensitive mode, and are equipped with a Transfer Trip System allowing the NWP to be tripped when the supplying primary feeder trips out from the station or is taken out of service.

14.2 Island operation

Islanding operation of the Microgrid system will be described in the following scenarios:

- **SCENARIO 1:** Following an area network blackout due to a large-scale event (weather related, earthquake, transmission line problem, etc.). In such a scenario if the Microgrid's DRs were already online, they would have likely tripped out due to the initial anti-islanding reaction per IEEE 1547. The generation capable of blackstart will then need to be started.
- **SCENARIO 2:** Pre-empting an area network blackout or avoiding risk due to a contingency condition. The transfer procedure that islands the Microgrid is done when deemed necessary in anticipation of a large scale system event. This could be any situation for which the Company EPS is in imminent danger of interruption, and as provided for under the terms and conditions of a Microgrid System Interconnection Agreement between the participating entities and the Company.

The islanding operation of Scenario 1 will proceed as follows:

14.2.1 Isolating the Microgrid from a de-energized Network

The Master Microgrid Controller (MMC) system will initiate and control the islanding process as follows:

14.2.1.1 The isolation switches and circuit breakers at the secondary intertie points (the MIDs) will be opened via remote control and their status of opening confirmed at the MMC's SCADA. The control power source for operating these switches and their data communication components will be station battery DC.

14.2.1.2 The network protectors will need to be manually opened locally, and then locked in open position. Their change in status from closed to open will be confirmed at the MMC's SCADA. Since the Grid is de-energized, there is no AC control power source for remotely opening the NWPs.

14.2.1.3 Disconnect loads on the de-energized Microgrid via remote control. Referred to as “Load Shedding**”**.

The MMC will disconnect all low priority connected loads by issuing a remote trip to the circuit breaker or switches at their respective switchgear throughout all the Microgrid participants’ facilities. Motor loads and other mechanical equipment, such as HVAC, can also be shed by preventing their restart through the use of commands issued to the building management systems within the Microgrid participants’ facilities. Load shed commands can be in the form of hard-wired relay contacts or via high speed data communication scheme.

Shedding the loads will help the Microgrid start-up smoothly without the instability caused by a large amount of load applied to the first online generator. The magnitude of current inrush and cold-load pickup will be staggered with time delay when the low priority loads are allowed to energize in a controlled, predictable sequence, rather than large block loading.

14.2.1.4 Protective Relay Settings

It will be necessary for the protective relay settings to be switched to the Microgrid island mode due to the change in short circuit level and electrical system configuration.

The MMC shall automatically enable the relays to change the protective relay settings, adapting to the operating mode of the Microgrid.

14.2.1.5 Black Starting

The MMC will initiate a black-start sequence to put generating units with black-start capability online and energizing the generator buses on emergency power.

The MMC will send a signal to change the settings of the generator protection relays for island mode operation as necessary.

14.2.1.6 Individual facility load re-energization

The Microgrid consists of several participating entities that have their own synchronous generators which they contribute to the Microgrid’s overall DER resource. These entities will behave as "sub-islands" during the blackstart stage of Microgrid islanding. The entities with synchronous generators will re-energize first and power the critical loads within their own facilities before releasing control to the MMC.

14.2.1.7 Creating the common generator paralleling bus:

After the MMC takes control, these sub-islands of synchronous generators will undergo the sequence of dead-bus closure, auto-synchronizing, and load sharing to create a stiff generator source using the secondary network as their paralleling bus.

14.2.1.8 Re-add of previously shed non-priority load:

As more synchronous generators are started-up and come online at the generator paralleling bus, the pre-selected loads that were previously shed can be re-energized in a controlled sequence according to programmed priority and amount of available online capacity. This is all supervised by the MMC. If a generator bus overload or underfrequency results after the re-addition of loads, then the last load priority to add will shed again.

14.2.1.9 Generator proportional load sharing:

The generator controllers shall be linked to the MMC via a high speed digital communication link – e.g. Ethernet LAN, in order to operate with other generating units in *isochronous load sharing mode* to ensure that the system's kW load is dynamically shared proportionately among the generators based on their rated capacity.

The parallel generators shall also share the system's kVAR requirements using *reactive power droop compensation mode.*

14.2.1.10 Start-up of other types of DER generators:

The islanded Microgrid will depend on synchronous generators (swing machines) to supply and regulate the voltage and frequency and provide a stiff reference bus for the other DER. After the required minimum 5 minute delay (IEEE 1547) the MMC monitors the subsequent reconnection of inverter-based generating units such as those driven by solar PV's, fuel cells, micro-turbines, wind-turbines, and CHP induction generators.

By controlling the paralleled synchronous generators, through high speed digital interface to fuel controllers and voltage regulators, the MMC shall control the frequency and voltage in the islanded system in accordance with the requirements of ANSI C84.1.

The islanding operation of Scenario 2 will proceed as follows:

14.2.2 Isolating the Microgrid system from an energized Network

The process of this scenario begins with the Microgrid already in a grid-connect mode and producing some power using the participating entities' DERs in accordance with the NY State Standard Interconnection Requirements (SIR), the Con Edison specification EO-2115, and separate amendments with Con Ed during the approval process of the particular Microgrid system.

The EPS is still operating normally or the service quality is still valid but the authority having control of the Microgrid determines that there is a need to separate.

The Master Microgrid Controller (MMC) system will initiate and control the islanding process as follows:

14.2.2.1 The MMC will be initiated to transition to island operation.

14.2.2.2 Whatever DER is already online will stay online and will maintain the same load level when it is set to behave autonomously. Synchronous generators in the Microgrid that are not normally dispatched in grid-connected operation, will receive a signal to start, synchronize, voltage match, and close their respective output breakers to the live bus connecting the generator facility to the secondary network outside. The MMC supervises the online status and breaker closing interlock.

14.2.2.3 The generators are now in a brief grid-connect mode while they transition the load off the area network.

MMC activates the voltage, frequency, and loading controls for all paralleled synchronous generators. These generators begin to slowly ramp their kW up, evenly and proportionally, while maintaining either a fixed PF or kVAR level.

14.2.2.4 As the synchronous generator power ramps up, the MMC will monitor the power across the MIDs (Interconnection Isolation Devices). When there is a low level of power flow into the Microgrid across any MID (i.e., the breaker is unloaded), the MID will be commanded to open. The MMC will then monitor the load across another MID and continue to ramp the generator power up until all MIDs are individually opened. Opening breakers or switches when they are conducting minimum load is desired because of the reduced wear and stress on the interrupting contacts.

14.2.2.5 Immediately upon the opening of the final MID, the MMC will switch all online synchronous generators to their Island mode controls for proportional load sharing as described in the previous scenario.

14.2.2.6 Protective Relay Settings

It may be necessary for the protective relay settings to switch dynamically between settings applicable to island and grid operating modes in order to adapt to the change in short circuit level and electrical system configuration.

The MMC shall automatically enable the relays to change their settings with changes in the Microgrid operating mode and system configuration.

14.2.2.7 It may be necessary to preempt the closed transition transfer with a load shedding of non-critical loads.

This was a seamless event as far as customer loads are concerned. No critical facility should have experienced an outage for this pre-emptive transfer into Island mode. No previously online DER should have disconnected.

14.2.2.8 The MMC will maintain most of the synchronous generators online in this scenario to act as the base reference for volts and Hz, as well as to maintain the stiffness of the Microgrid in absorbing transient block load increases.

By controlling the paralleled synchronous generators, through high speed digital interface to fuel controllers and voltage regulators, the MMC shall control the frequency and voltage in the islanded system in accordance with the requirements of ANSI C84.1.

14.3 Transitioning the Microgrid from island mode back to parallel mode

Reconnection of the Microgrid can be initiated when the surrounding Network is restored, and the minimum stabilization time of 5 minutes (adjustable) has expired.

14.3.1 Closed-transition reconnection *(preferred method)*

14.3.1.1 Reconnection Point:

The Microgrid will have multiple Microgrid Intertie Points. These are the secondary switches and circuit breakers that interconnect the secondary main cables of the Microgrid to the main cables of the surrounding Network. When portions of the Microgrid are supplied from spot networks, the network protectors (NWP) are the intertie points to the primary distribution system.

Closed-transition switching will involve selecting the one device that will be closed first to lock the Microgrid into the wider system – the Network. The first device can be selected from among the circuit breakers used as the Microgrid Interconnection Device. The breaker selected shall be equipped with a sync-check relay that will permit the closing of the breaker only when the proper synchronizing conditions are met (i.e., phase angle, voltage, and freq. differential between sources) in accordance with the IEEE 1547 requirements.

14.3.1.2 Synchronizing Parameters – Refer to Section 7.6

14.3.1.3 Active Synchronizing

"Active" synchronizing is used, as opposed to "passive" synchronizing which just waits until the slip rate of the generator source brings it within an acceptable phase angle of the utility source. Active

synchronizing is faster and allows precise control for "*phase locking*". This is a better method for closed transition switching, and reduced stress on equipment. The MMC shall have the capability to perform active synchronizing. A typical system does this through digital signals from the MMC, via the LAN, that activates a dedicated "*master auto-synchronizer*", which is built into the same package that controls load sharing and voltage. This master auto-synchronizer can be wired for 1- or 3-phase voltage sensing on both sides of the synchronizing intertie-point breaker. It can either do this with direct bus taps or PTs. The auto-synchronizer transmits its own signals, via the LAN, to all the online generator speed controllers. This will cause all connected synchronous generators to speed up or slow down to sync with the utility source. The synchronizer's software PID loop is effectively "shifting" the frequency of the whole Microgrid by small increments up and down.

The auto-synchronizer will seek to *phase lock* across the synchronizing breaker and to hold it steady for a "*dwell time*" of about 1.0 seconds, or a specified time duration that both sources have to be within the threshold parameters as specified in IEEE1547.

The voltage matching capability of the synchronizer, can manipulate the voltage by sending commands to the Microgrid power control system, which in turn will dynamically adjust the regulators for all online generators. This is done in small increments of raise/lower commands through contact closures wired into regulators, or analog signals wired into regulators. The basis of successful voltage matching is counting on all generators in all locations of the macro-island behaving with equal response to the raise and lower commands. Problems with circulating current and kVAR overload occur when some generators react faster to others when given the same control signal for the same duration. If voltage matching is working well, it can match the generator bus to within 3% of the utility reference. This results in low current shift between the Microgrid and the rest of the utility network at the moment of reconnection.

The MMC shall be equipped with the capability to phase-lock the Microgrid in synchronism with the Grid across the chosen MID circuit breaker.

The ability to synchronize the Microgrid is dependent on how well the MMC and local generator controls can adjust voltage and frequency of all the synchronous generators in parallel. The rest of the online DER would simply follow the conditions at their intertie point.

Once proper synchronizing conditions are achieved and confirmed by sync check relays, the MMC will send the close command to the selected MID breaker.

Upon confirming that the breaker closed, the MMC will immediately switch the modes of the synchronous generators' voltage regulators and loading controls for grid-connect operation. The MMC shall also cause the protective relays to switch over to the grid connection settings.

The remaining MID breakers and/or switches can be closed in rapid succession at this point because all these tie points will now be in sync with the EPS network after that first breaker closed.

14.3.1.4 Reconfiguring the Microgrid to grid-connect mode after closed transition.

When the pre-determined number of the secondary MIDs has been closed into the area network, the Microgrid shall be reconfigured to grid-connect operating mode as follows.

- The MMC will ramp down the loading of the synchronous generators and trip them off the Microgrid. However, depending on short circuit current levels, type of fuel, rate structure, Company exception, etc., synchronous generators may be allowed to stay online, producing power, in continuous grid connected mode as part of a Microgrid peak shaving or export contract.

- The inverters and induction types of DER would have remained online and will not be affected by this closed transition into Grid-Connect mode. Those forms of DER will stay online in Grid-Connect mode after the synchronous generators shut down and return to their Auto/Standby mode.
- The MMC can release the “block-open” signal to the network protectors and allow the network protectors to reclose when their autonomous reclosing conditions are satisfied. If this is not possible, Company crews will need to manually release the block-open.

14.3.2 Open transition

Another way of reconnecting the Microgrid from island mode to normal grid-connect is with open-transition switching. When the area network system is restored and the minimum stability period (5 mins) has elapsed, the transition from island mode to grid-connect mode can be initiated.

The procedure and sequence of operation will proceed as follows:

14.3.2.1 The Master Microgrid Controller (MMC) system will start turning off the low priority loads in a controlled sequence, using load shed commands, and allowing for the generating units to dynamically adjust their voltage and frequency after each level of shedding.

14.3.2.2 The MMC will manage the balance of generation and load and can ramp down the loading of the synchronous generators or can trip and shutdown units as additional loads are switched off the islanded Microgrid.

14.3.2.3 Induction Generators and Inverter-Based generating units are taken offline proactively, or will be forced offline when the final synchronous generator is disconnected from the Microgrid.

14.3.2.4 The process involving switching off loads and synchronous generation can proceed gradually until the entire Microgrid is completely shutdown. Only isolated emergency generators working inside customer facilities, without any connection to the Microgrid, will be online.

14.3.2.5 The MMC will verify the voltages across all the Microgrid intertie points.

14.3.2.6 The MMC will confirm that a stable voltage is present on the area network side, and a zero voltage on the Microgrid side. Upon successful confirmation, the MMC will issue a closing signal to all the breakers and switches at the secondary Microgrid intertie points, energizing the secondary mains and the high priority loads that were not load shed.

14.3.2.7 The MMC can release the block-open “signal” to the network protectors allowing them to close when the proper reclosing parameters are satisfied.

14.3.2.8 The MMC can start reconnecting the loads back, by releasing the load shed signals and reclosing the low priority load switches and breakers.

14.3.2.9 The distributed resources can be allowed to come back on line in their grid-connect mode.

15.0 APPENDIX B

Operation of a typical Microgrid System in the Auto-Loop System

15.1 Grid-Connected Operation

The embedded DER's in the Microgrid can be successfully interconnected and operated in parallel with the auto-loop system by following the guidelines and requirements of the NY State Standard Interconnection Requirements (SIR) and the Con Edison specification EO-2115.

15.2 Island operation

Islanding operation of the Microgrid system will be described in the following scenarios:

- **SCENARIO 1:** *Following an outage of the auto-loop section to where the Microgrid is interconected due a fault or a large-scale event (weather related, earthquake, transmission network problem, etc.)*. In such a scenario if the Microgrid's DERs were already online, they would have likely tripped out due to the initial anti-islanding reaction per IEEE 1547. The generation capable of blackstart will then need to be started.
- **SCENARIO 2:** *Pre-empting a system-wide blackout or avoiding risk due to a contingency condition*. The transfer procedure that islands the Microgrid is done when deemed necessary in anticipation of a large scale system event. This could be any situation for which the Company service is in imminent danger of interruption, and as provided under the terms and conditions of a Microgrid System Interconnection Agreement between the participating entities and the Company.
- The islanding operation of Scenario 1 will proceed as follows:

15.2.1 Isolating the Microgrid System from a de-energized auto-loop section:

The Master Microgrid Controller (MMC) system will initiate and control the islanding process as follows:

15.2.1.1 The Intertie Circuit Breaker will be opened via remote control and their status of opening confirmed at the MMC's SCADA. The control power source for operating the intertie breaker, and associated data communication components, will be a DC station battery system.

15.2.1.2 Disconnect loads on the de-energized Microgrid via remote control. Referred to as "Load Shedding".

The MMC will disconnect all low priority connected loads by issuing a remote trip to the circuit breaker or switches at their respective switchgear throughout all the Microgrid participants' facilities. Motor loads and other mechanical equipment, such as HVAC, can also be shed by preventing their restart through the use of commands issued to the building management systems within the Microgrid participants' facilities. Load shed commands can be in the form of relay contacts or high speed data communication.

Shedding the loads will help the Microgrid start-up smoothly without the instability caused by a large amount of load applied to the first online generator. The magnitude of current inrush and cold-load pickup will be staggered with time delay when the low priority loads are allowed to energize in a controlled, predictable sequence, rather than large block loading.

15.2.1.3 Protective Relay Settings

It may be necessary for the protective relay settings to switch between settings applicable to island and grid operating modes in order to dynamically adapt to the change in short circuit level and electrical system configuration.

The MMC shall automatically enable the relays to change their settings depending on the operating mode.

15.2.1.4 Black Starting

The MMC will initiate a black-start sequence to put generating units with black-start capability online and energizing the generator buses on emergency power.

The MMC will send a signal to change the settings of the generator protection relays for island mode operation as necessary.

15.2.1.5 Individual facility load re-energization

The Microgrid consists of several participating entities that have their own synchronous generators which they contribute to the Microgrid's overall DER. These entities behave as "sub-islands" during the blackstart stage of Microgrid islanding. The entities with synchronous generators will re-energize first and power the critical loads within their own facilities before releasing control to the MMC.

15.2.1.6 Creating the common generator paralleling bus:

After the MMC takes control, these sub-islands of synchronous generators will undergo the sequence of dead-bus closure, auto-synchronizing, and load sharing to create a stiff generator source though the Microgrid's common interconnection conductors.

15.2.1.7 Re-add of previously shed non-priority load:

As more synchronous generators are started-up and come online at the generator paralleling bus, the pre-selected loads that were previously shed can be re-energized in a controlled sequence according to programmed priority and amount of available online capacity. This is all supervised or controlled by the MMC. If a generator bus overload or underfrequency results after the re-addition of loads, then the load with the lowest priority will shed again.

15.2.1.8 Generator proportional load sharing:

The generator controllers shall be linked to the MMC via a high speed digital communication link – e.g. Ethernet LAN, in order to operate with other generating units in *isochronous load sharing mode* to ensure that the system's kW load is dynamically shared proportionately among the generators based on their rated capacity.

The parallel generators shall also share the system's kVAR requirements using *reactive power droop compensation mode.*

15.2.1.9 Start-up of other types of DER generators:

The islanded Microgrid will depend on synchronous generators (swing machines) to supply and regulate the voltage and frequency and provide a stiff reference bus for the other DER. After the required minimum 5 minute delay (IEEE 1547) the MMC monitors the subsequent reconnection of inverter-based generating units such as those driven by solar PV's, fuel cells, micro-turbines, wind-turbines, and CHP induction generators.

By controlling the paralleled synchronous generators, through high speed digital interface to fuel controllers and voltage regulators, the MMC shall control the frequency and voltage in the islanded system in accordance with the requirements of ANSI C84.1.

- The islanding operation of Scenario 2 will proceed as follows:

15.2.2 Isolating the Microgrid System from an <u>energized</u> auto-loop system.

In this scenario, the process begins with the Microgrid already in a grid-connect mode and producing some power. While the EPS may still be energized and operating normally, but the authority having control of the Microgrid determines that there is a need to separate.

The Master Microgrid Controller (MMC) system will initiate and control the islanding process as follows:

15.2.2.1 A representative from the local Microgrid authority will initiate an islanding command to the MMC.

15.2.2.2 Whatever DER is already online will stay online and maintain its same load level since it is behaving autonomously. The synchronous generators of this Microgrid will receive a signal to start, synchronize, voltage match, and close their respective output breakers to the live bus connecting the generator facility to the outside system. The MMC supervises the online status and breaker closing interlock.

15.2.2.3 The synchronous generators are now in a brief grid-connect mode while they transition the load off the area network. MMC activates the voltage, frequency, and loading controls for all paralleled synchronous generators. These generators begin to slowly ramp their kW up, evenly and proportionally, while maintaining either a fixed PF or kVAR level.

As the synchronous generator power ramps up, the MMC will monitor the power across the Intertie Point. When there is a low level of power flow into the Microgrid across the Intertie Point, the Intertie Circuit Breaker will be commanded to open.

15.2.2.4 Immediately upon the opening Intertie Breaker, the MMC will switch all online synchronous generators to their Island mode controls for proportional load sharing as described in the previous scenario.

15.2.2.5 Protective Relay Settings

It may be necessary for the protective relay settings to switch between settings applicable to island and grid operating modes in order to dynamically adapt to the change in short circuit level and electrical system configuration.

The MMC shall automatically enable the relays to change their settings depending on the present mode.

15.2.2.6 No load shedding was necessary for this closed transition transfer.

This was a seamless event as far as customer loads are concerned. No facility should have experienced an outage for this pre-emptive transfer into Island mode. No previously online DER should have disconnected.

15.2.2.7 The MMC will maintain most of the synchronous generators online in this scenario to act as the base reference for volts and Hz, as well as to maintain the stiffness of the islanded Microgrid in absorbing transient block load increases.

By controlling the paralleled synchronous generators, through high speed digital interface to fuel controllers and voltage regulators, the MMC shall control the frequency and voltage in the islanded system in accordance with the requirements of ANSI C84.1.

15.3 Transitioning the Microgrid from Island mode back to Grid-Connect

Reconnection of the Microgrid to the radial auto-loop system can be initiated when the auto-loop section has been restored, and the minimum stabilization time of 5 minutes (adjustable) has been met.

Transition switching can be undertaken similar to the procedures as described in APPENDIX A Section 14.0 for Microgrid operating in the Network.

16.0 REFERENCE DIAGRAMS – AUTO-LOOP SYSTEMS

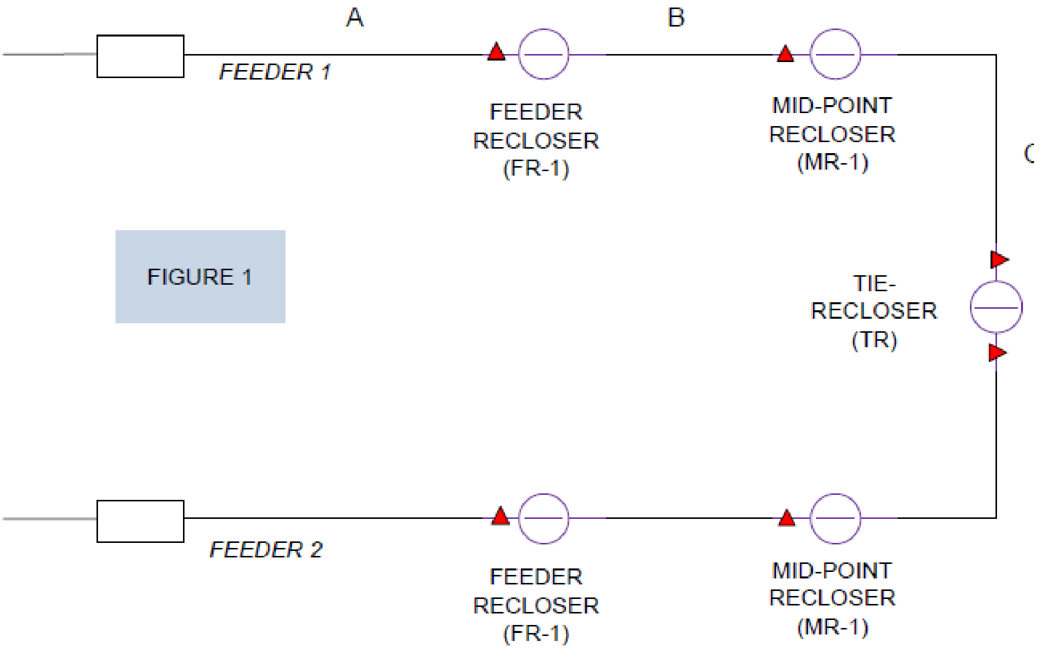


FIGURE 1

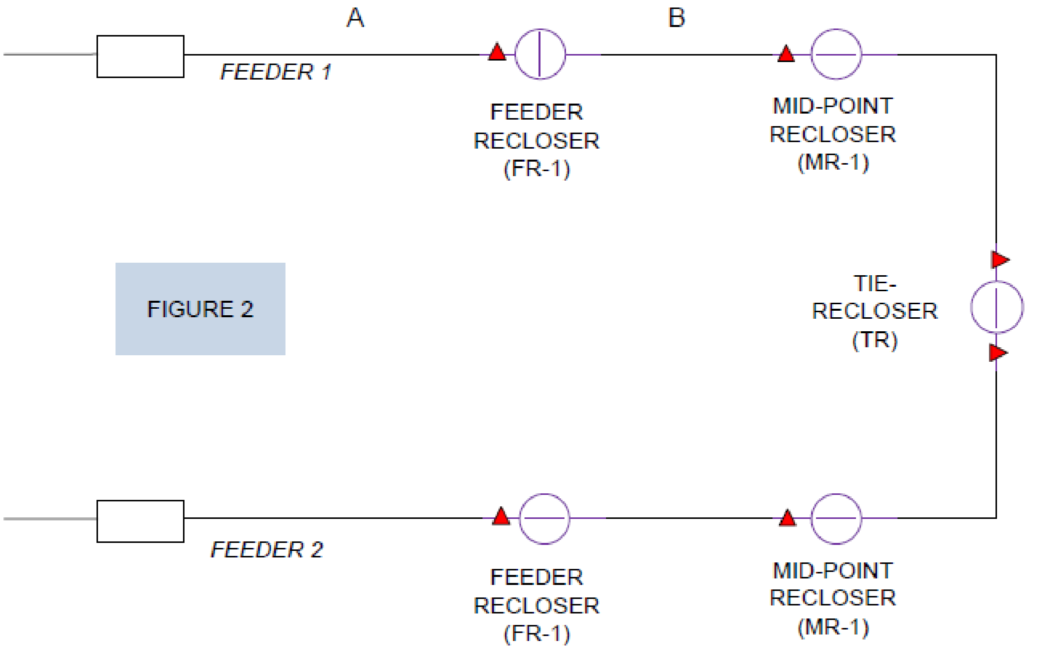


FIGURE 2

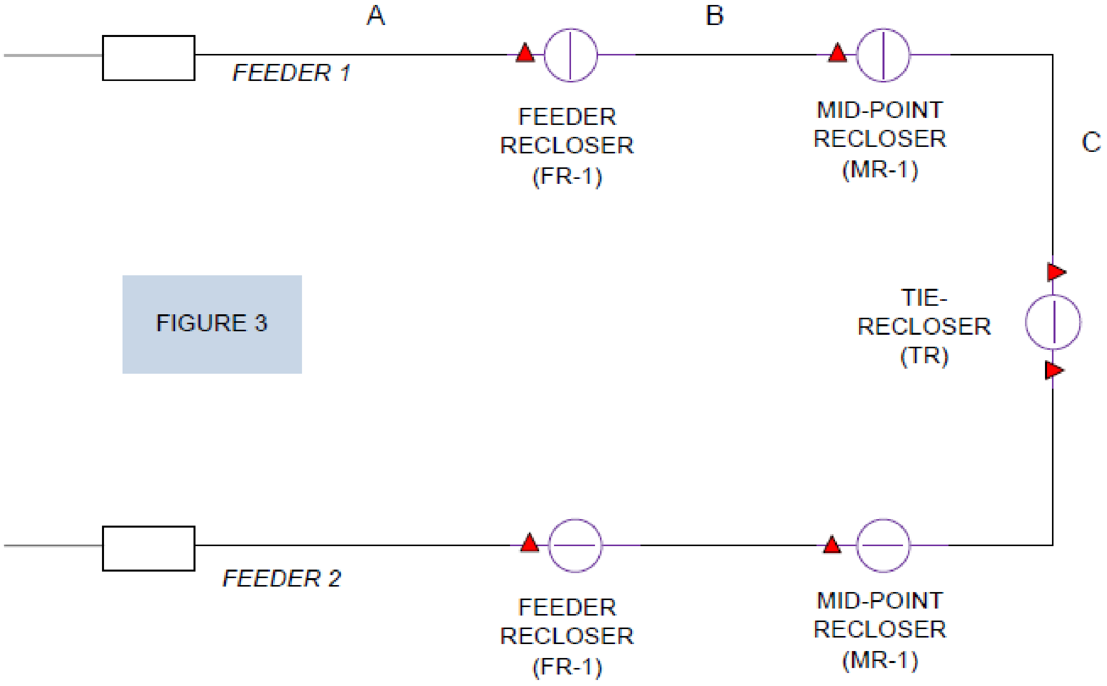


FIGURE 3

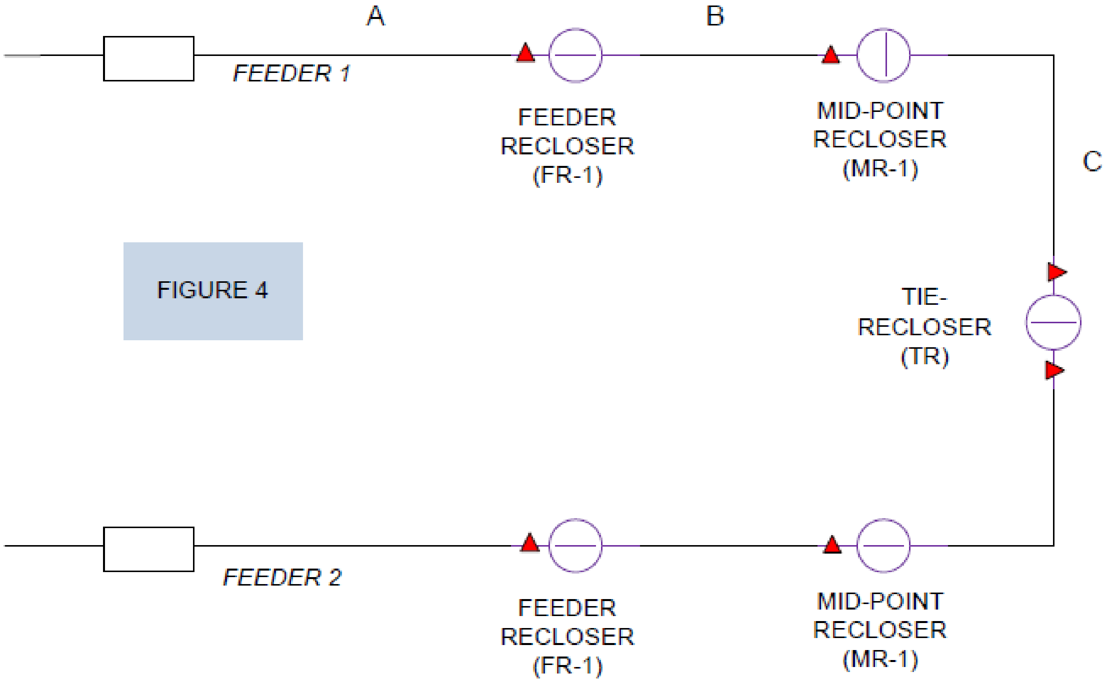
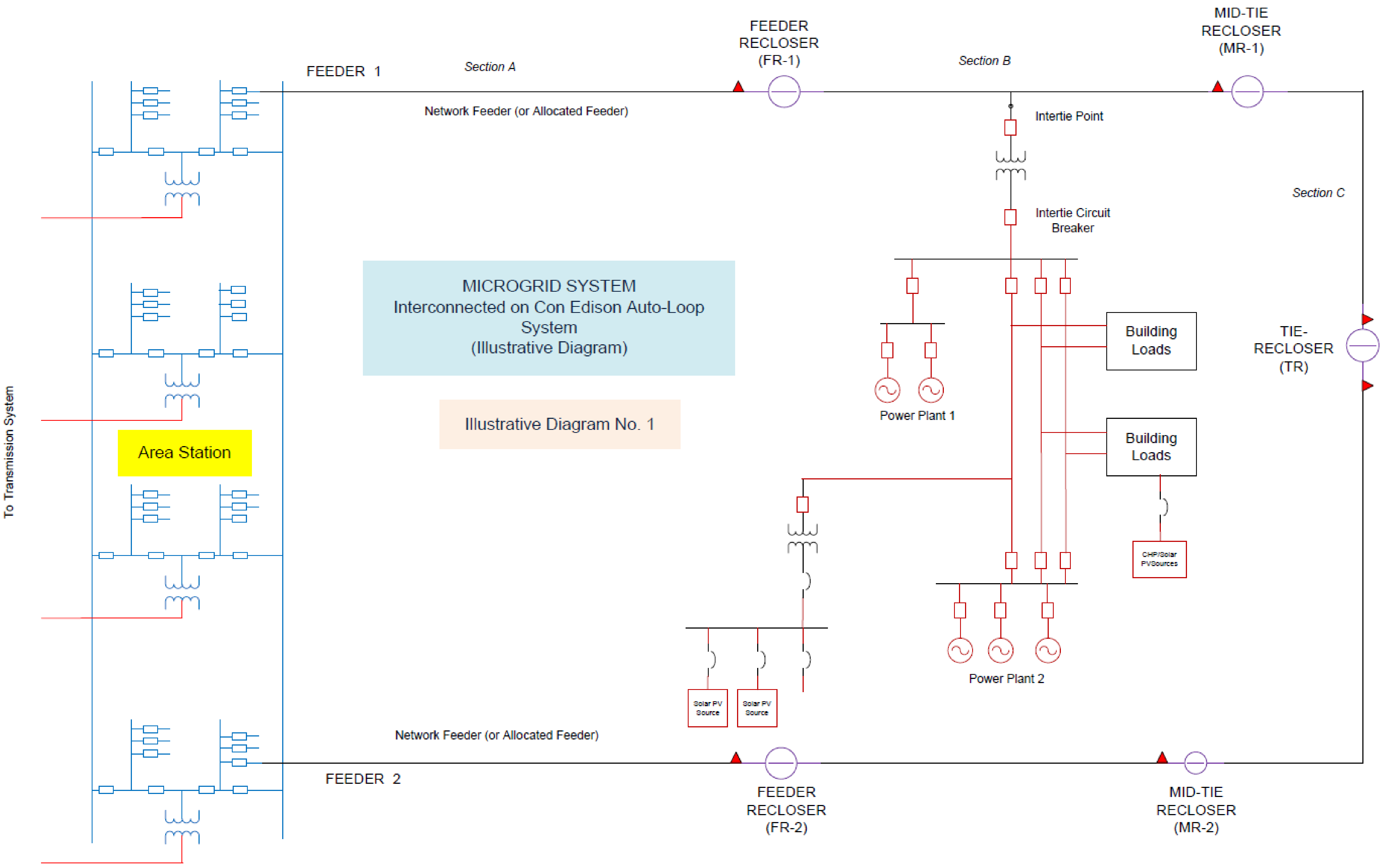
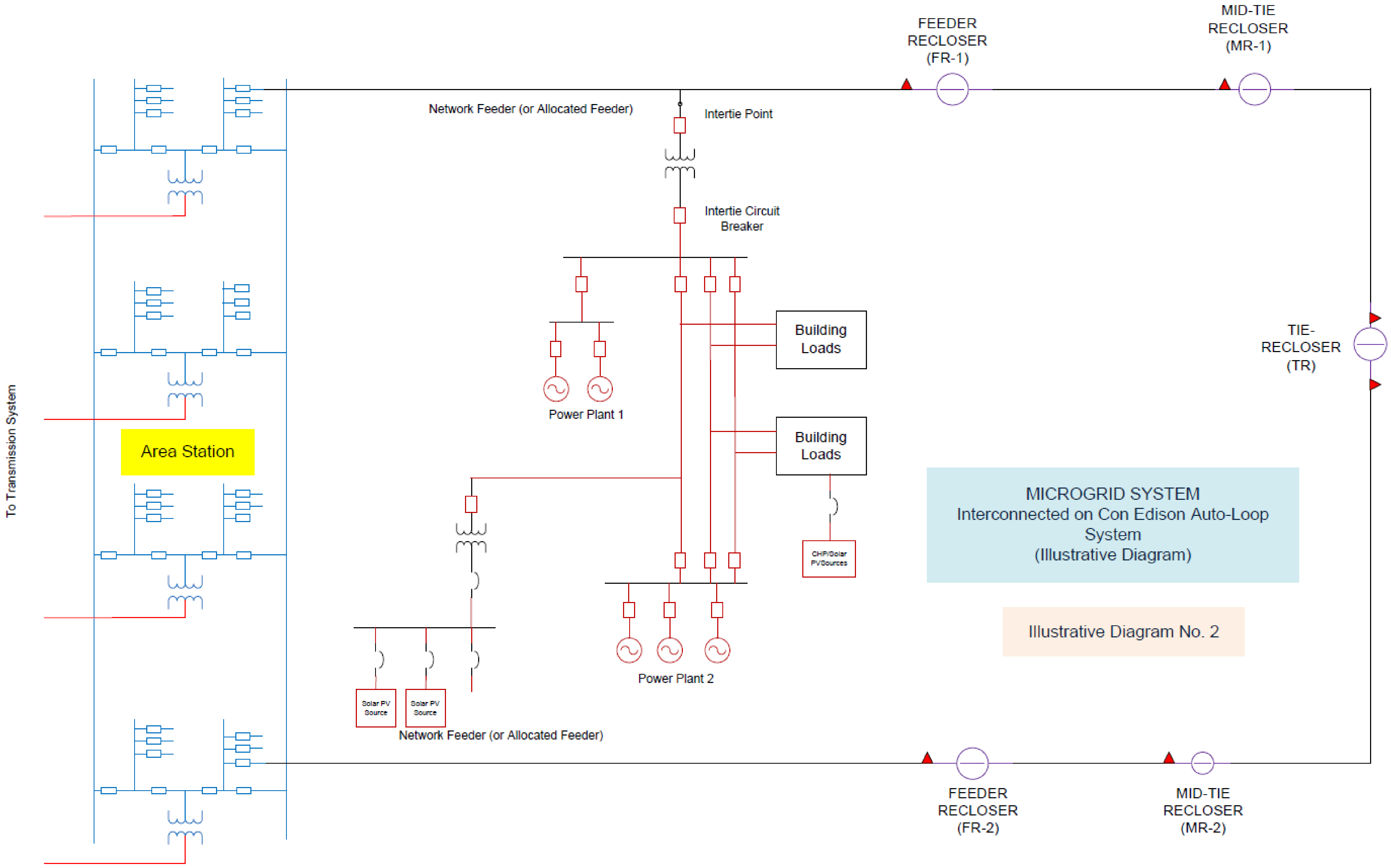


FIGURE 4


MICROGRID SYSTEM
Interconnected on Con Edison Auto-Loop System
(Illustrative Diagram)
Illustrative Diagram No. 1
FEEDER 1
Section A
Network Feeder (or Allocated Feeder)
FEEDER RECLOSER (FR-1)
Section B
MID-TIE RECLOSER (MR-1)
Intertie Point
Intertie Circuit Breaker
Section C
TIE-RECLOSER (TR)
Building Loads
Building Loads
Power Plant 1
Power Plant 2
CHP/Solar PV Sources
Solar PV Source
Solar PV Source
To Transmission System
Area Station
Network Feeder (or Allocated Feeder)
FEEDER 2
FEEDER RECLOSER (FR-2)
MID-TIE RECLOSER (MR-2)


FEEDER RECLOSER (FR-1)
MID-TIE RECLOSER (MR-1)
Network Feeder (or Allocated Feeder)
Intertie Point
Intertie Circuit Breaker
Building Loads
Building Loads
Power Plant 1
TIE-RECLOSER (TR)
To Transmission System
Area Station
MICROGRID SYSTEM
Interconnected on Con Edison Auto-Loop System
(Illustrative Diagram)
CHP/Solar PVSources
Illustrative Diagram No. 2
Solar PV Source
Solar PV Source
Power Plant 2
Network Feeder (or Allocated Feeder)
FEEDER RECLOSER (FR-2)
MID-TIE RECLOSER (MR-2)

17.0 ILLUSTRATIVE SECONDARY “NETWORK” SYSTEM MICROGRID