

# *LEADING THE WAY* **CampusEnergy**2022

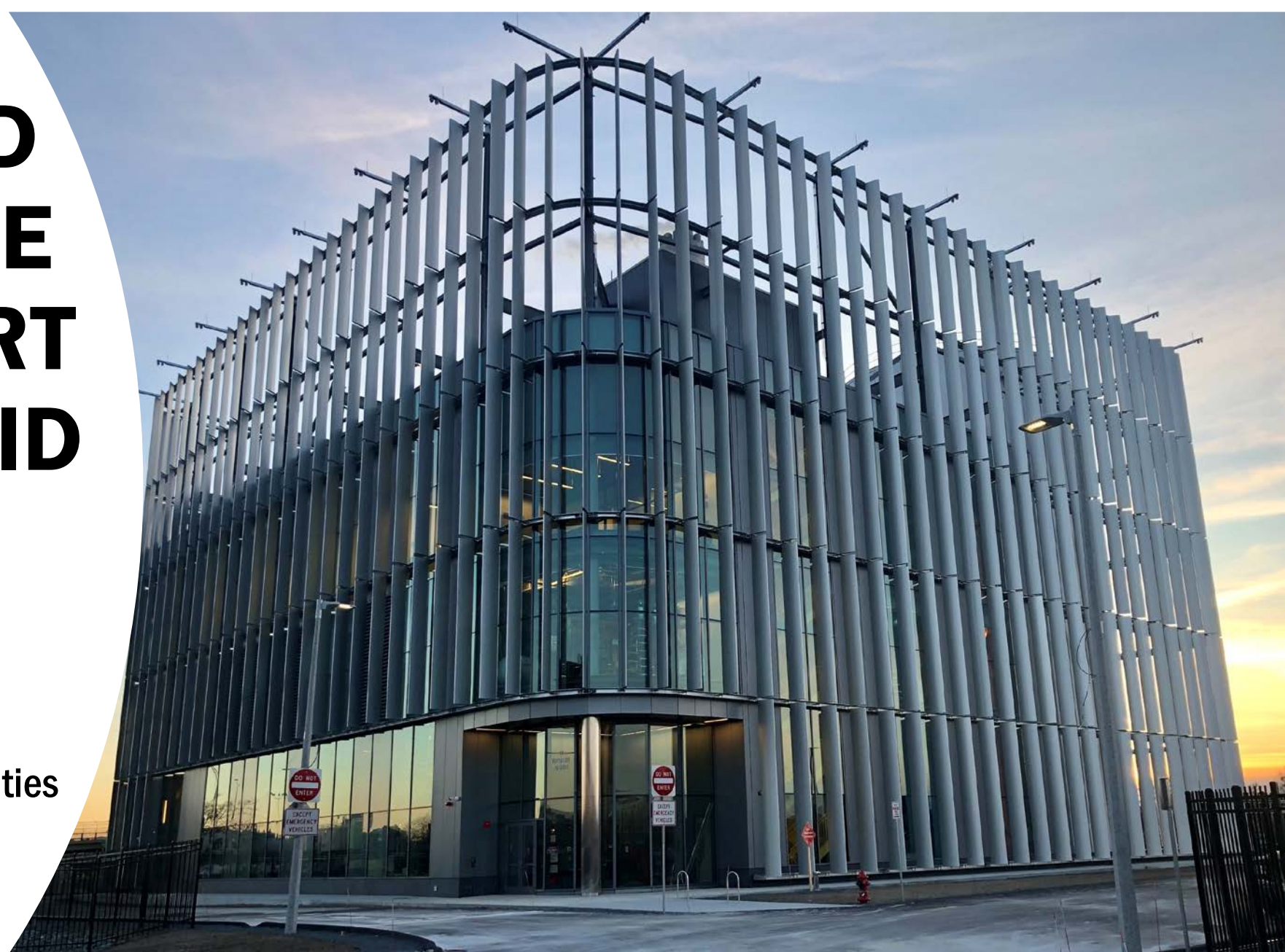
Feb. 15-18 | Westin Boston Seaport District Hotel | Boston, Mass.



# HARVARD DEF STATE OF THE ART MICROGRID

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RMF Engineering, Inc.

**Bob Manning**  
Harvard Engineering & Utilities



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Reliability. Efficiency. Integrity.



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# HARVARD DISTRICT ENERGY FACILITY

## TECHNOLOGY OVERVIEW



### DAY 1 OPERATION VS. 50 YEAR PLANNING

DAY 1 EQUIPMENT IN FULLY BUILT PLANT



### 5,000 TON NOW | 17,500 TON TOTAL

CHILLER PLANT



### 1.4 MILLION GALLON TES (14,000 TON HOUR)

### 260 TON HEAT RECOVERY CHILLER

GREEN TECHNOLOGIES



### 46,000 MBH | 146,000 MBH TOTAL

DUAL FUEL CONDENSING HOT WATER GENERATORS



### 4 MW NOW | 6 MW TOTAL

STANDBY POWER



### 2.5MW NOW | 7.5 MW TOTAL

COGEN POWER

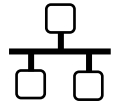


### 12 MW NOW | 24 MW TOTAL

MV DISTRIBUTED POWER

# HARVARD DEF – PROJECT CHALLENGES

## PROJECT CHALLENGES



**ROBUST/ FLEXIBLE SWGR  
CONTROL SYSTEM**



**< 8 CALORIE INCIDENT ENERGY**



**SAFE OPERATOR INTERACTION**



**COGEN WITH FULL EXPORT  
CAPABILITY**

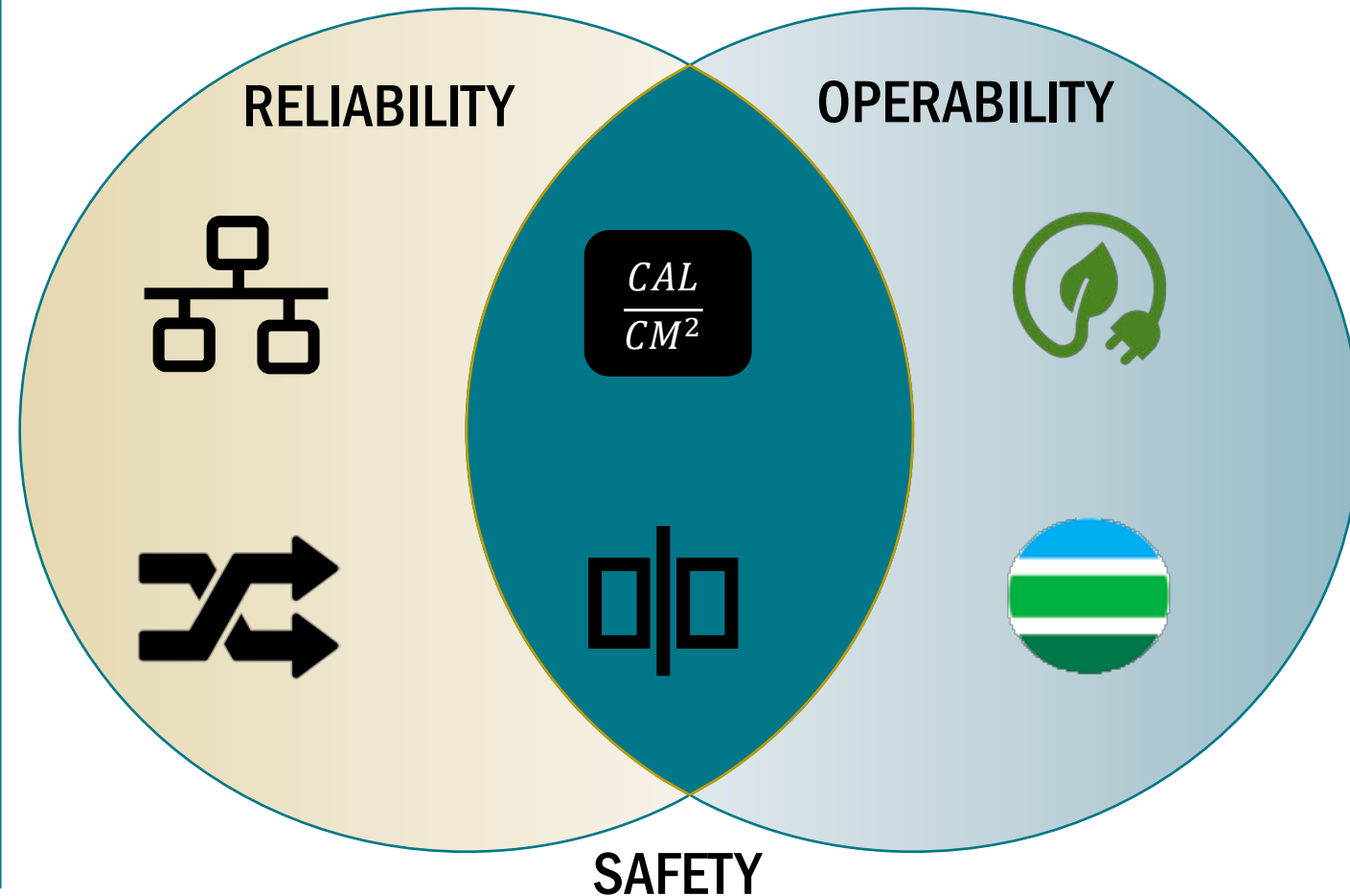


**INCORPORATE GREEN  
TECHNOLOGY**



**NO SINGLE POINTS OF FAILURE**

## PROJECT APPROACH



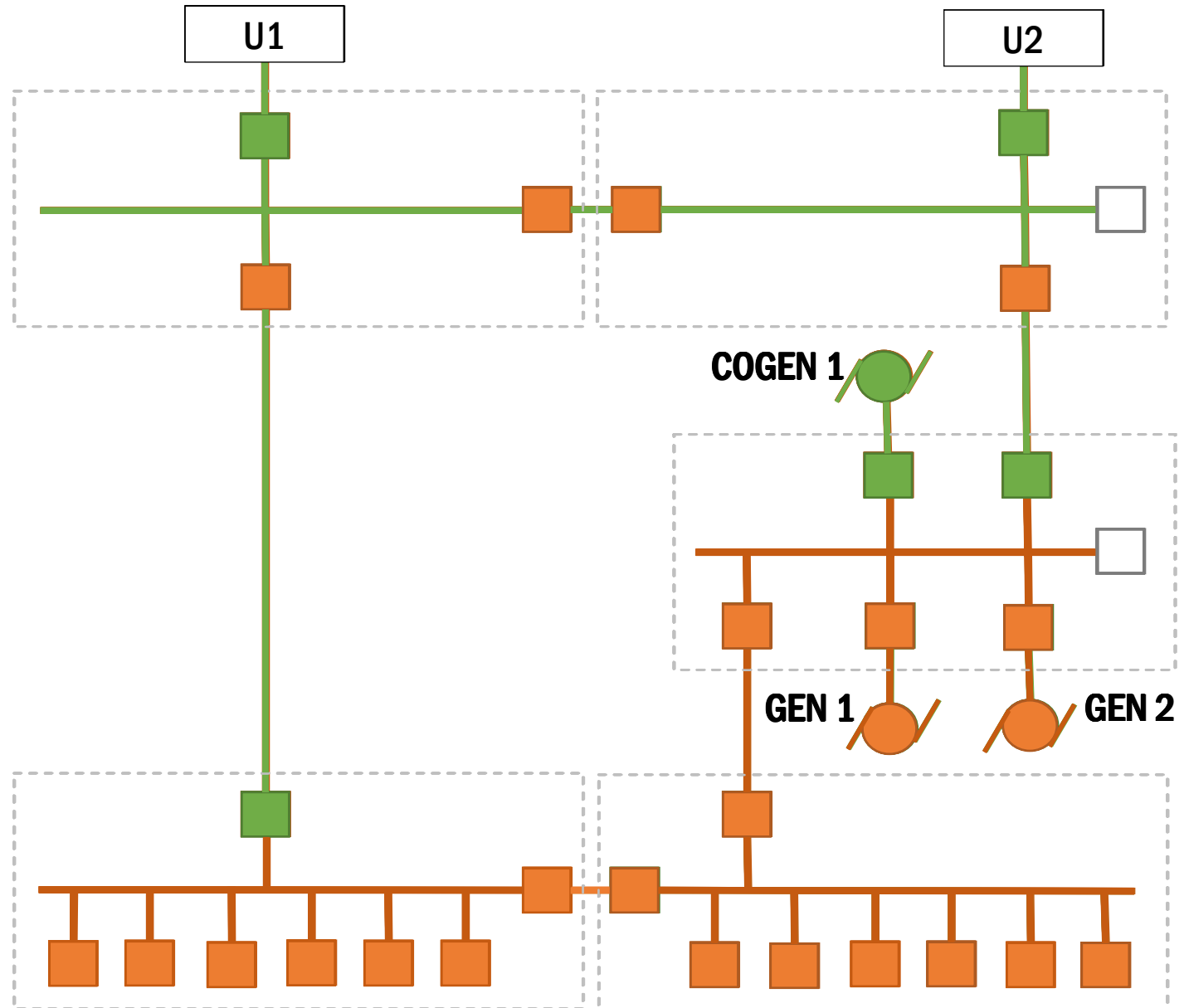
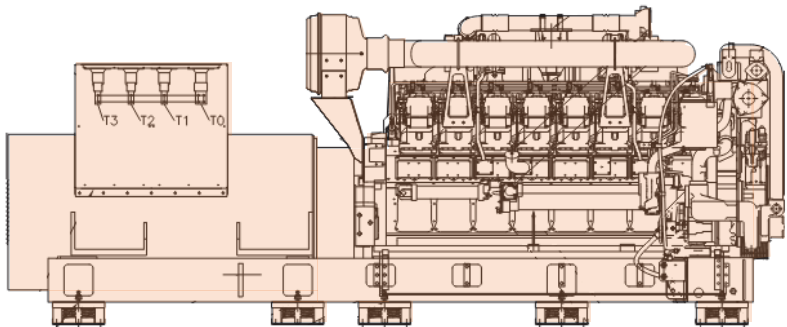
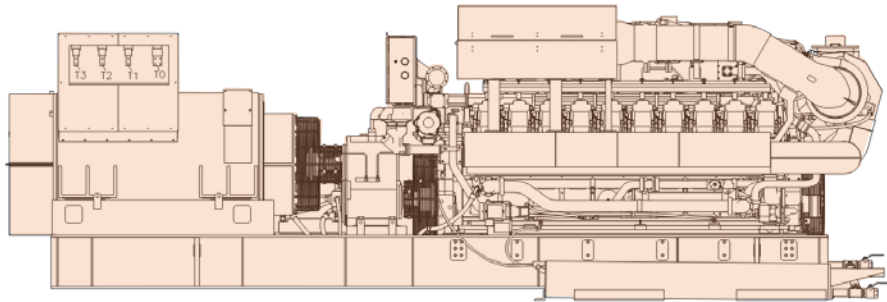
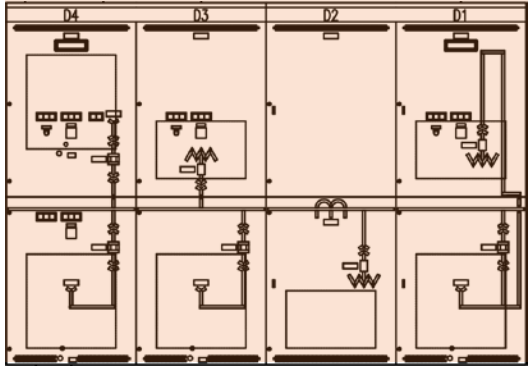
# DESIGN FOCUS - RELIABILITY

- **PLC-Based Switchgear and Generator Control System**
- **Synchronizes multiple standby and Cogen engines**
- **Seamless generator testing**
- **Island mode operation**
- **Full export capability**



# DESIGN FOCUS – RELIABILITY

POWER SOURCE: STANDBY (BUS OUTAGE)



# DESIGN FOCUS - RELIABILITY



**13.8 kV  
Switchgear: Total  
of 30 Sections**

**Remote Operator  
Panels: Total of  
19 Sections**



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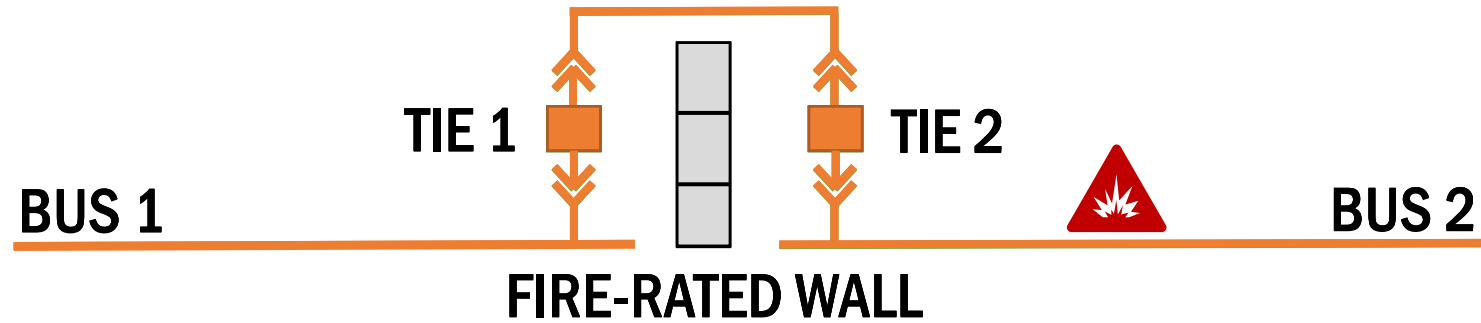


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# DESIGN FOCUS - RELIABILITY

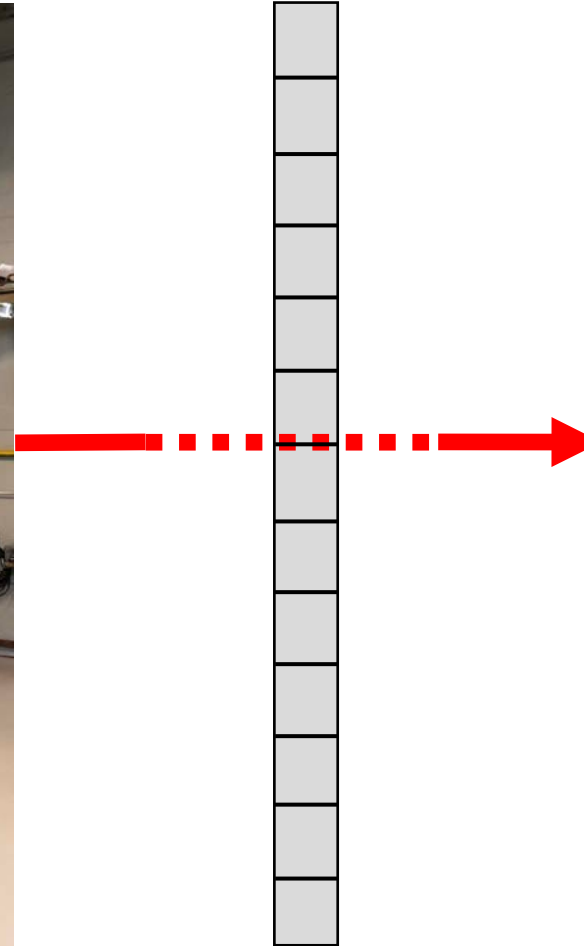


# COMMITTED TO SAFETY – OPERATOR SEPARATION

13,800 VOLT SWITCHGEAR –  
EQUIPMENT OPERATION



FIRE-RATED WALL



120V REMOTE PANELS –  
HUMAN INTERACTION



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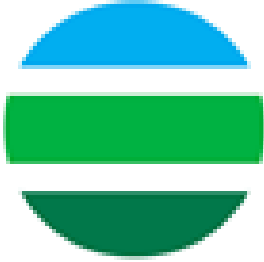


# COMMITTED TO SAFETY – 480V SYSTEM

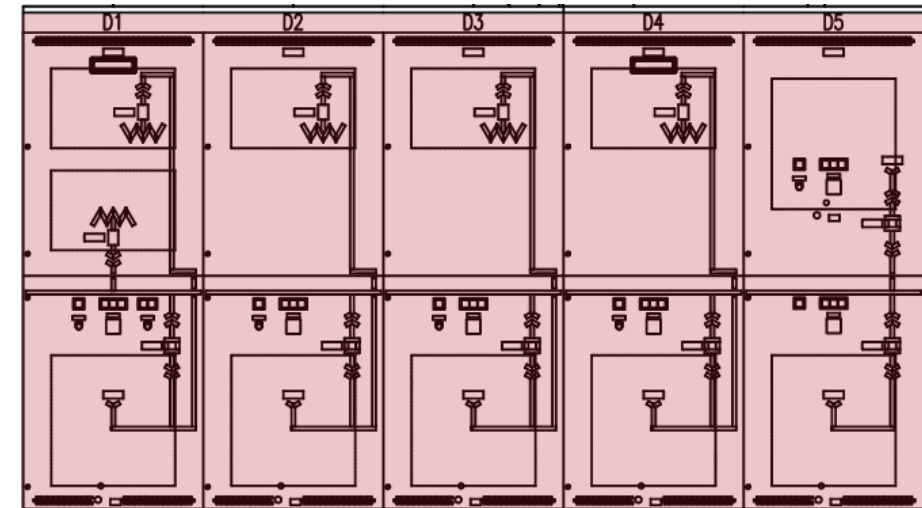
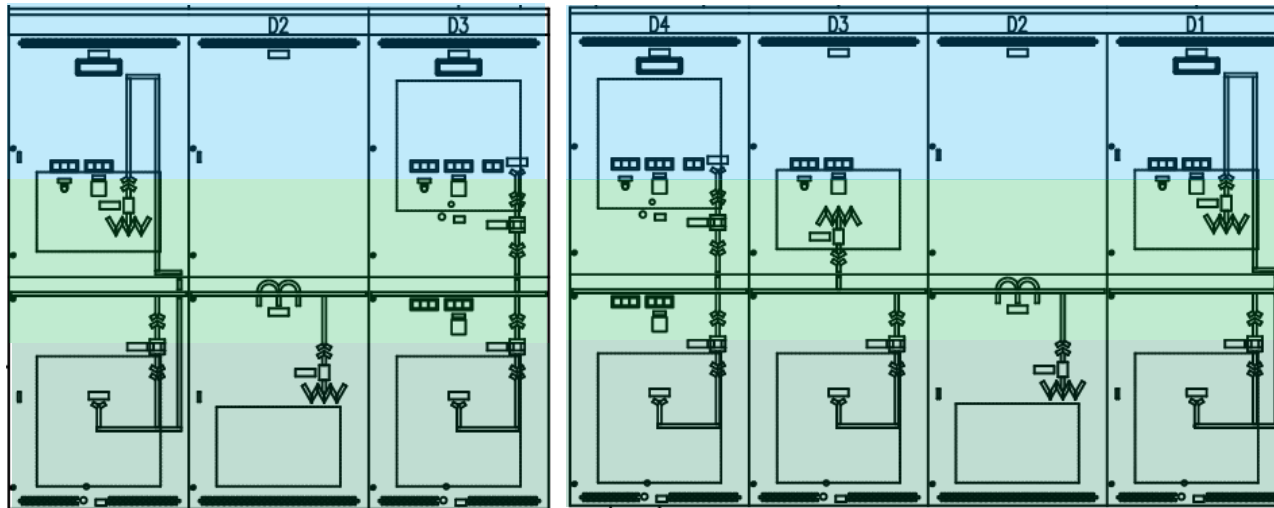
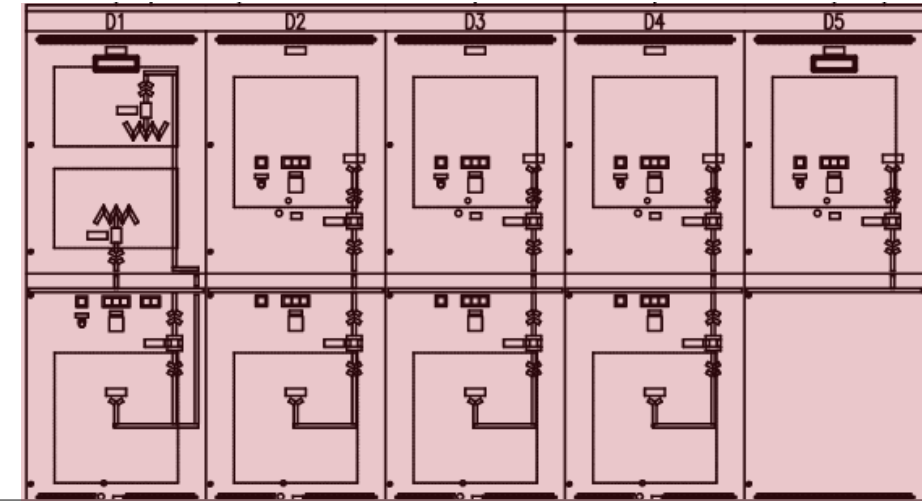
- › **Secondary unit substations**
  - › High resistance ground
  - › Remote control 13.8 kV switches and 3000A breakers
  - › Diversified mechanical loads



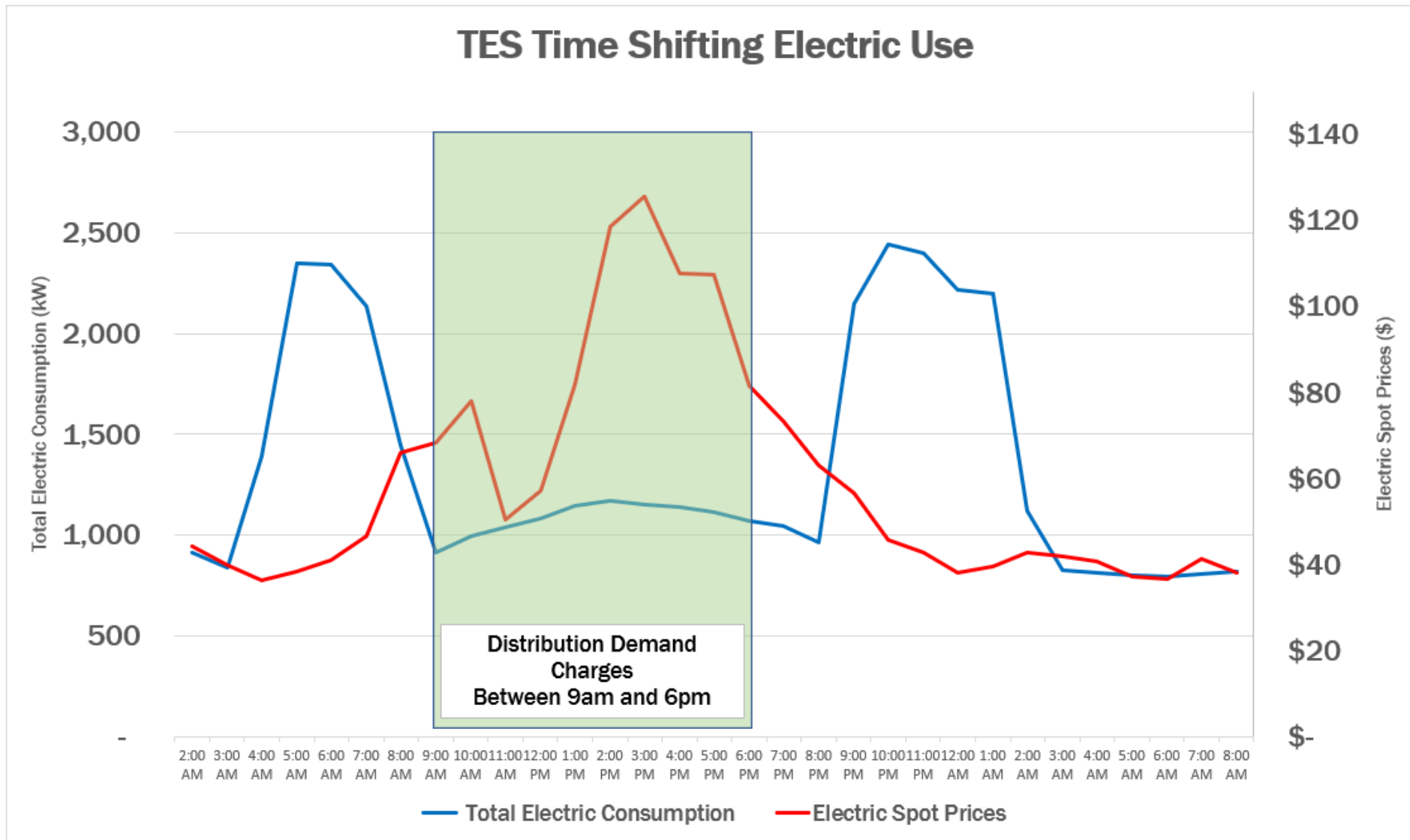
# SYSTEM OPERATION - UTILITY/HARVARD EQUIPMENT



Physically Separated by Operator (Min. 2HR Wall)



# SYSTEM OPERATION – TES LOAD SHIFTING



# SYSTEM OPERATION - COGEN

CO-GEN - PEAK SHAVE

| DESCRIPTION                       | SETPOINT | ACTUAL | UNITS |
|-----------------------------------|----------|--------|-------|
| Increase Generator Capacity       | 0        | 0      | %kW   |
| Increase Generator Capacity Timer | 0        | 0      | Sec.  |
| Decrease Generator Capacity       | 0        | 0      | %kW   |
| Decrease Generator Capacity Timer | 0        | 0      | Sec.  |
| Import kW                         | 0        | 0      | kW    |

PEAK SHAVE  
MODE  
DIS. ENABLE

CO-GEN  
MODE  
MIN-IMP THERM

ISLAND  
MODE  
DIS. ENABLE



## Modes of Operation

- › Thermal Following (Full Export Capability)
- › Minimum Import

## Control Methodology

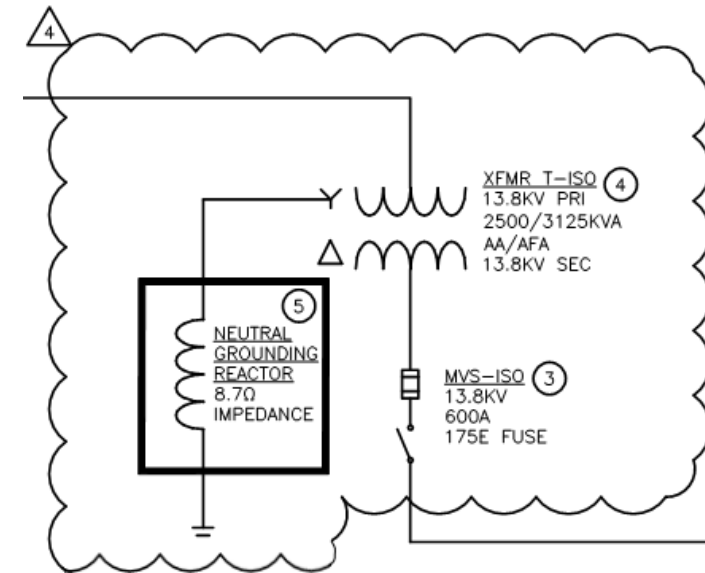
- › Customer Reliability Focuses (No ride-thru)
- › IEEE 1547 Intertie Protection

## Interaction

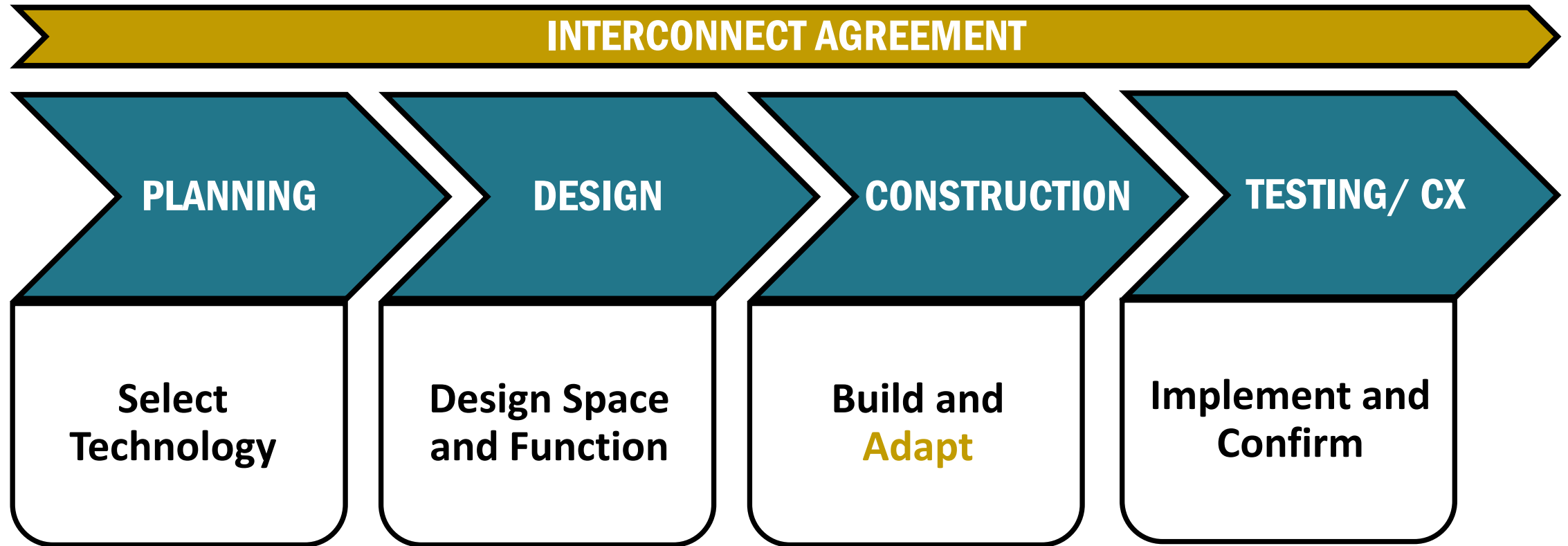
- › Automated
- › Manual Override

# SYSTEM OPERATION – UTILITY INTERCONNECT

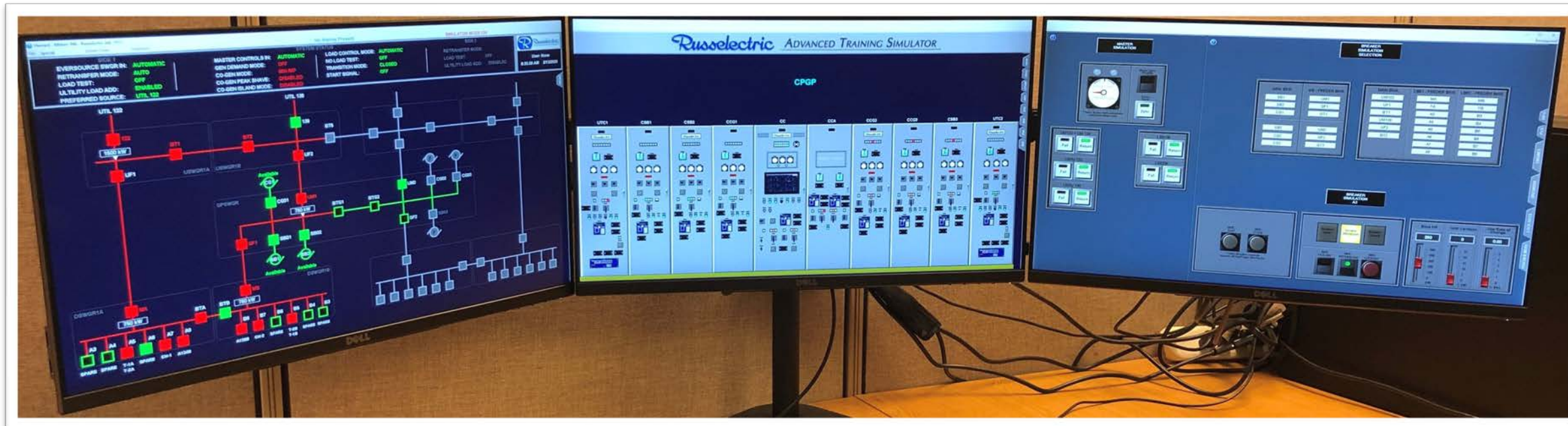
- **Interconnect Agreement**
  - Multiple meetings with public utility during design
  - Influential client
  - Space planned for outcome of system impact study (SIS)
- **Field Changes Required (Outcome of SIS):**
  - Isolation transformer installed on future cogen pad
  - Creative, team-oriented solutions



# MANAGING UTILITY INTERCONNECTION PROCESS



# SYSTEM OPERATION – SIMULATOR



**Operator Training**



**System Troubleshooting**



**System Testing**

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## Harvard DEF - Switchgear Operating Scenarios Matrix

Date: 11/3/2020

| Everource SWGR                     | Distribution SWGR     | Generator SWGR                     | ABR Switch | A/M Switch | Scenario      | System Action      | Notes                                                                 |
|------------------------------------|-----------------------|------------------------------------|------------|------------|---------------|--------------------|-----------------------------------------------------------------------|
| Normal Utility Operating Scenarios |                       |                                    |            |            |               |                    |                                                                       |
| UTIL 1 Preferred                   | Split                 | Cogen Available                    | Auto       | Auto       | UTIL 1 Outage | Transfer to UTIL 2 |                                                                       |
| UTIL 1 Preferred                   | Split                 | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 1 Outage | Transfer to UTIL 2 | Generators will start but not connect to bus on dual utility loss.    |
| UTIL 1 Preferred                   | Split                 | Cogen Available                    | Manual     | Auto       | UTIL 1 Outage | Enter Standby Mode | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1 |
| UTIL 1 Preferred                   | Fed from MB           | Cogen Available                    | Auto       | Auto       | UTIL 1 Outage | Transfer to UTIL 2 |                                                                       |
| UTIL 1 Preferred                   | Fed from MB           | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 1 Outage | Transfer to UTIL 2 | Generators will start but not connect to bus on dual utility loss.    |
| UTIL 1 Preferred                   | Fed from MB           | Cogen Available                    | Manual     | Auto       | UTIL 1 Outage | Enter Standby Mode | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1 |
| UTIL 1 Preferred                   | Fed from MA, UM1 Open | Cogen Available                    | Auto       | Auto       | UTIL 1 Outage | Transfer to UTIL 2 |                                                                       |
| UTIL 1 Preferred                   | Fed from MA, UM1 Open | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 1 Outage | Transfer to UTIL 2 | Generators will start but not connect to bus on dual utility loss.    |
| UTIL 1 Preferred                   | Fed from MA, UM1 Open | Cogen Available                    | Manual     | Auto       | UTIL 1 Outage | Enter Standby Mode | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1 |
| UTIL 1 Preferred                   | Fed from MA, MB Open  | Cogen Available                    | Auto       | Auto       | UTIL 1 Outage | Transfer to UTIL 2 |                                                                       |
| UTIL 1 Preferred                   | Fed from MA, MB Open  | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 1 Outage | Transfer to UTIL 2 | Generators will start but not connect to bus on dual utility loss.    |
| UTIL 1 Preferred                   | Fed from MA, MB Open  | Cogen Available                    | Manual     | Auto       | UTIL 1 Outage | Enter Standby Mode | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1 |
| UTIL 2 Preferred                   | Split                 | Cogen Available                    | Auto       | Auto       | UTIL 2 Outage | Transfer to UTIL 1 |                                                                       |
| UTIL 2 Preferred                   | Split                 | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 2 Outage | Transfer to UTIL 1 | Generators will start but not connect to bus on dual utility loss.    |
| UTIL 2 Preferred                   | Split                 | Cogen Available                    | Manual     | Auto       | UTIL 2 Outage | Enter Standby Mode | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1 |
| UTIL 2 Preferred                   | Fed from MB           | Cogen Available                    | Auto       | Auto       | UTIL 2 Outage | Transfer to UTIL 1 |                                                                       |
| UTIL 2 Preferred                   | Fed from MB           | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 2 Outage | Transfer to UTIL 1 | Generators will start but not connect to bus on dual utility loss.    |
| UTIL 2 Preferred                   | Fed from MB           | Cogen Available                    | Manual     | Auto       | UTIL 2 Outage | Enter Standby Mode | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1 |
| UTIL 2 Preferred                   | Fed from MA, UM1 Open | Cogen Available                    | Auto       | Auto       | UTIL 2 Outage | Transfer to UTIL 1 |                                                                       |

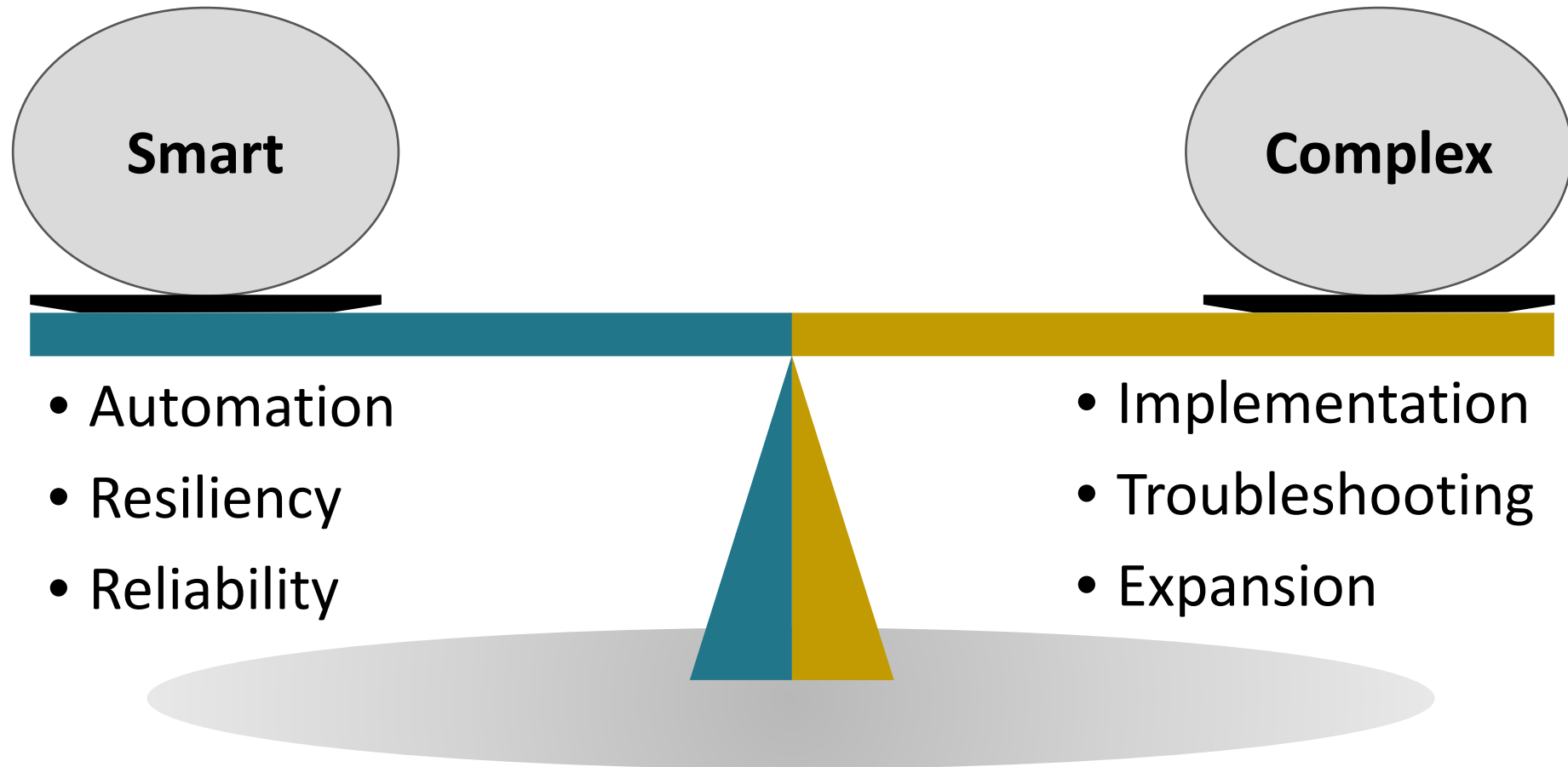
## Harvard DEF - Switchgear Operating Scenarios Matrix

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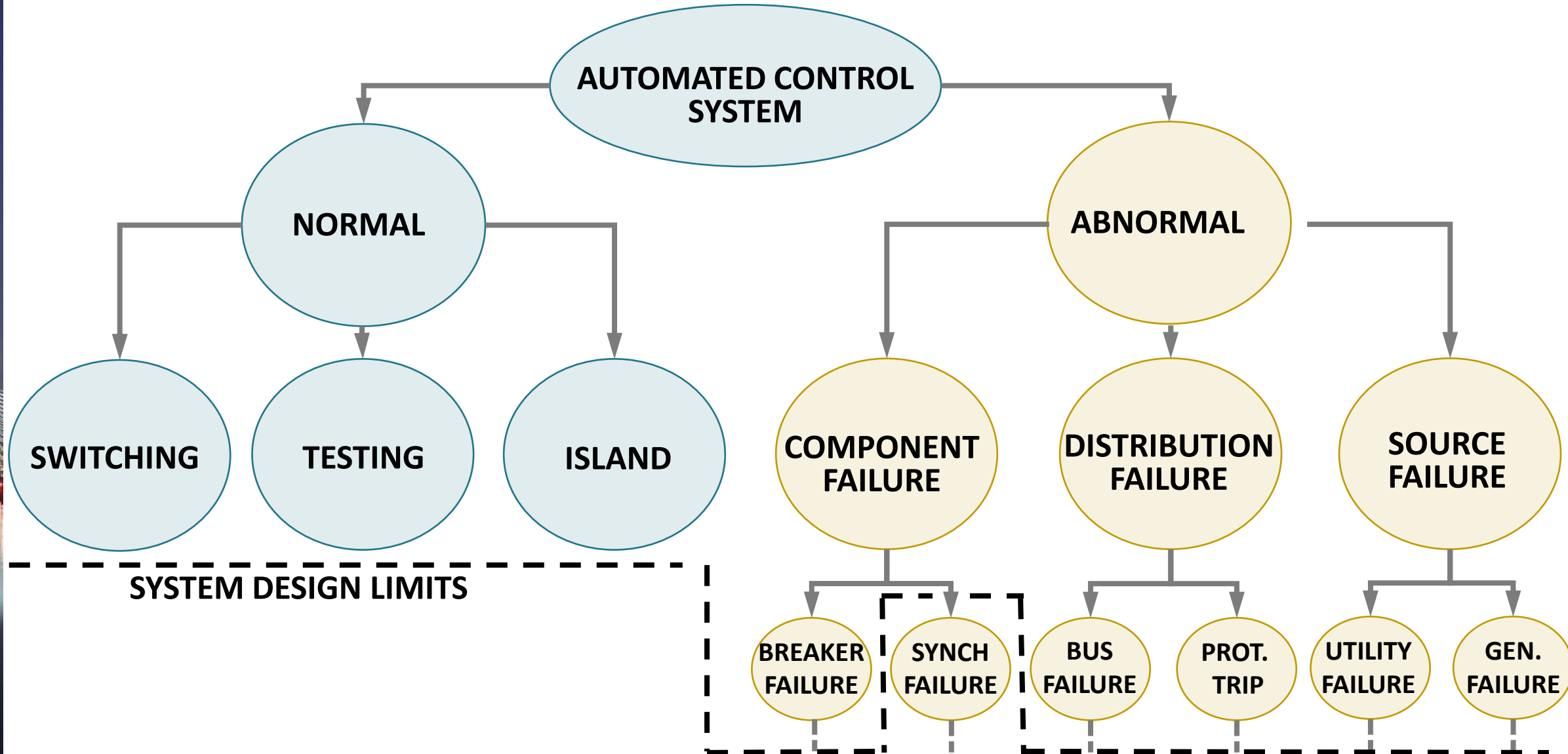
| Everource SWGR | Distribution SWGR   | Generator SWGR                     | ABR Switch | A/M Switch | Scenario      | System Action           | Notes                                                                                                                                                                               |
|----------------|---------------------|------------------------------------|------------|------------|---------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Split          | Split/ B Bus Outage | Cogen - Thermal Only               | Auto       | Auto       | UTIL 1 Outage | Transfer to UTIL 2      | Generators will power DIST BUS A through Eversource SWGR in event of dual utility outage. E&U must coordinate with Eversource to shutoff generators prior to Eversource retransfer. |
| Split          | Split/ B Bus Outage | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 1 Outage | Transfer to UTIL 2      | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| Split          | Split/ B Bus Outage | Cogen - Thermal Only               | Manual     | Auto       | UTIL 1 Outage | DIST BUS A AND B OUTAGE | The ABR scheme will not transfer or OPEN UTIL 1 breaker. There is no path for generation to DSWGR BUS A. DSWGR BUS A remains de-energized.                                          |
| Split          | Split/ B Bus Outage | Cogen - Thermal Only               | Auto       | Auto       | UTIL 2 Outage | Transfer to UTIL 1      | Generators will power DIST BUS A through Eversource SWGR in event of dual utility outage. E&U must coordinate with Eversource to shutoff generators prior to Eversource retransfer. |
| Split          | Split/ B Bus Outage | Cogen Unavailable (DIST in MANUAL) | Auto       | Manual     | UTIL 2 Outage | Transfer to UTIL 1      | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| Split          | Split/ B Bus Outage | Cogen - Thermal Only               | Manual     | Auto       | UTIL 2 Outage | DIST BUS A AND B OUTAGE | The ABR scheme will not transfer or OPEN UTIL 2 breaker. There is no path for generation to DSWGR BUS A. DSWGR BUS A remains de-energized.                                          |
| Split          | Split/ B Bus Outage | Cogen - Thermal Only               | Auto       | Auto       | Dual Outage   | Enter Standby Mode      | Generators will power DIST BUS A through Eversource SWGR in event of dual utility outage. E&U must coordinate with Eversource to shutoff generators prior to Eversource retransfer. |

|                            |                       |                                    |        |        |               |                      |                                                                                                                                                                                     |
|----------------------------|-----------------------|------------------------------------|--------|--------|---------------|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Split                      | Fed from MB           | Cogen Available                    | Auto   | Auto   | UTIL 2 Outage | Transfer to UTIL 1   |                                                                                                                                                                                     |
| Split                      | Fed from MB           | Cogen Unavailable (DIST in MANUAL) | Auto   | Manual | UTIL 2 Outage | Transfer to UTIL 1   | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| Split                      | Fed from MB           | Cogen Available                    | Manual | Auto   | UTIL 2 Outage | MA Closes            | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1                                                                                                               |
| Split                      | Fed from MA, UM1 Open | Cogen Available                    | Auto   | Auto   | UTIL 2 Outage | Transfer to UTIL 1   |                                                                                                                                                                                     |
| Split                      | Fed from MA, UM1 Open | Cogen Unavailable (DIST in MANUAL) | Auto   | Manual | UTIL 2 Outage | Transfer to UTIL 1   | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| Split                      | Fed from MA, UM1 Open | Cogen Available                    | Manual | Auto   | UTIL 2 Outage | No transfer required | ABR will not transfer at Eversource SWGR, DIST SWGR still energized.                                                                                                                |
| Split                      | Fed from MA, MB Open  | Cogen - Thermal Only               | Auto   | Auto   | UTIL 2 Outage | Transfer to UTIL 1   | Cogen thermal following mode only.                                                                                                                                                  |
| Split                      | Fed from MA, MB Open  | Cogen Unavailable (DIST in MANUAL) | Auto   | Manual | UTIL 2 Outage | Transfer to UTIL 1   | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| Split                      | Fed from MA, MB Open  | Cogen - Thermal Only               | Manual | Auto   | UTIL 2 Outage | No transfer required | Cogen thermal following mode only. ABR will not transfer at Eversource SWGR, DIST SWGR still energized.                                                                             |
| Outage Operating Scenarios |                       |                                    |        |        |               |                      |                                                                                                                                                                                     |
| UTIL 2 Preferred           | Split/ Bus A Outage   | Cogen Available                    | Auto   | Auto   | UTIL 2 Outage | Transfer to UTIL 1   |                                                                                                                                                                                     |
| UTIL 2 Preferred           | Split/ Bus A Outage   | Cogen Unavailable (DIST in MANUAL) | Auto   | Manual | UTIL 2 Outage | Transfer to UTIL 1   | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| UTIL 2 Preferred           | Split/ Bus A Outage   | Cogen Available                    | Manual | Auto   | UTIL 2 Outage | Enter Standby Mode   | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1                                                                                                               |
| UTIL 1 Preferred           | Split/ Bus A Outage   | Cogen Available                    | Auto   | Auto   | UTIL 1 Outage | Transfer to UTIL 2   |                                                                                                                                                                                     |
| UTIL 1 Preferred           | Split/ Bus A Outage   | Cogen Unavailable (DIST in MANUAL) | Auto   | Manual | UTIL 1 Outage | Transfer to UTIL 2   | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| UTIL 1 Preferred           | Split/ Bus A Outage   | Cogen Available                    | Manual | Auto   | UTIL 1 Outage | Enter Standby Mode   | ABR will not transfer at Eversource SWGR - restoration at DIST SWGR-1                                                                                                               |
| UTIL 2 Preferred           | Split/ Bus B Outage   | Cogen Available                    | Auto   | Auto   | UTIL 2 Outage | Transfer to UTIL 1   | Generators will power DIST BUS A through Eversource SWGR in event of dual utility outage. E&U must coordinate with Eversource to shutoff generators prior to Eversource retransfer. |
| UTIL 2 Preferred           | Split/ Bus B Outage   | Cogen Unavailable (DIST in MANUAL) | Auto   | Manual | UTIL 2 Outage | Transfer to UTIL 1   | Generators will start but not connect to bus on dual utility loss.                                                                                                                  |
| UTIL 2 Preferred           | Split/ Bus B Outage   | Cogen - Thermal Only               | Manual | Auto   | UTIL 2 Outage | DIST BUS A OUTAGE    | The ABR scheme will not transfer or OPEN UTIL 2 breaker. There is no path for generation to DSWGR BUS A. DSWGR BUS A remains de-energized.                                          |
| UTIL 1 Preferred           | Split/ Bus B Outage   | Cogen Available                    | Auto   | Auto   | UTIL 1 Outage | Transfer to UTIL 2   | Generators will power DIST BUS A through Eversource SWGR in event of dual utility outage. E&U must coordinate with Eversource to shutoff generators prior to Eversource retransfer. |

# BALANCING SYSTEM AUTOMATION PHILOSOPHY



# BALANCING SYSTEM AUTOMATION PHILOSOPHY



# **LESSONS LEARNED**



**Commit to  
Safety**



**Balance  
Functionality and  
Complexity**



**Plan for and  
Adapt to Utility  
Requirements**



# Questions?



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# THANK YOU!

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