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## FREDERICK WASTE WATER TREATMENT PLANT

BATTERY ENERGY STORAGE SYSTEM

# SWITCHGEAR "US-M1" & TESLA ENERGY STORAGE SEQUENCE OF OPERATIONS

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# EXECUTIVE SUMMARY

## PROJECT UNDERSTANDING

The existing Ballenger-McKinney Waste Water Treatment Plant in Frederick, Maryland is in the process of installing a new Tesla energy storage system to ensure reliable power to critical loads. A new Tesla battery bank and inverter package is planned to be connected to the existing switchgear lineup "US-M1" with a Main-Tie-Main arrangement with dual utility connections via 34.5kV/480V step-down transformers.

The existing switchgear has an auto-transfer scheme driven by a discontinued Modicon Quantum 140-CPU-671-60 controller. The existing logic will need to be modified, at minimum, to integrate with the new Tesla system, as well as a separate "Islanding Controller" (based on the SEL-700G), as required by Tesla.

Critical loads exist on both sides of the switchgear bus, and the Automatic Transfer scheme has previosly been operated with the Tie breaker normally open and both Main breakers normally closed. The new Tesla BESS system is being connected to a previously spare breaker "52-5D" on one side of the bus, and will be used to power critical loads during brief outages of both utility feeds.

## MODIFICATIONS TO EXISTING DOCUMENTATION

This document is intended to modify and extend the Sequence of Operations described in the Square D switchgear documentation to integrate the Tesla Battery Energy Storage System (BESS) at the Ballenger-McKinney ENR Wastewater Treatment Plant.

The Square D documentation used as a reference for this Sequence of Operations is identified by Square D Factory Order/Quotation/Project Number 26961730 with the following revision dates:

- Drawings: November 10, 2010
- Sequence of Operations: October 1, 2008

The original Sequence of Operations has be re-produced here, with any modifications, additions, or changes highlighted in yellow.

# SEQUENCE OF OPERATIONS

## START-UP INTO AUTOMATIC OPERATION

The following steps can be used to place the switchgear, Island BOS, and Tesla system back into Automation Operation after an outage, trip, or other unusual condition:

1. Place the Auto/Manual Selector Switch in the "Manual" position.
2. Check that the Programmable Logic Controller (PLC) green run light is on (located on PLC).
3. Check that the touchscreen has rebooted and has no alert symbols near any elements.
4. Reset Overcurrent Trip Switches (SDE), and trip indicators on normal power main and generator breakers
5. Rack breakers completely into the "CONNECTED" position.
6. Close and trip breakers using the Breaker Control Push Buttons on the touchscreen. Push buttons are only operable with Auto/Man selector switch in the "MANUAL" position.
7. Check that normal voltages to normal power mains are present, close normal power main breakers.
8. Press the "SYSTEM SETTINGS" button on the touchscreen to modify or view adjustable settings. Set Source Stabilization and Loss Delays, Transition Timer (time between one breaker opening and the next breaker closing during normal operation) and password timeout delays. Press the "MAIN PAGE" button on the touchscreen to return to the Main screen.
9. Check that the "MANUAL" pilot light is on, place the Auto/Man Selector Switch in the "AUTO" position, and confirm that the "AUTO" pilot light is on, indicating proper start-up. (If the start-up fails, the "AUTO-FAIL" light will indicate. If this occurs, check the trouble-shooting section and repeat the start-up sequence.) Auto Fail prevents the system from operating automatically on fault and emergency trip conditions.
10. Confirm that the 11U relay (SEL-700G) does not have any Target indicator lights illuminated.
11. Confirm that the Tesla system has all alarms cleared and is ready for normal operations.
12. Confirm that the Island BOS touchscreen has all active alarms cleared, the 43SYS switch is in the "AUTO" position, and that the "Master Permissive" light is green on the "Permissives" screen.

Note: Start-up sequence should be repeated when maintenance is performed on equipment.

## SWITCHGEAR AUTOMATIC OPERATION

The following sections describe the proper automatic operation of the Main-Tie-Main switchgear, Island BOS, and Tesla energy storage system:

### A. NORMAL CONDITIONS

1. Main breakers "52-M1" and "52-M2" are closed.
2. Tie breaker "52-T" is open.
3. The Auto/Man selector switch is in the "AUTO" position.
4. The Auto Retransfer switch is in the "ON" position.
5. The Island BOS touchscreen 43SYS switch is in the "AUTO" position.

### B. NORMAL POWER FAILED ON MAIN "52-M1" or "52-M2"

1. Voltage failure is deteced by device 27/47-1 or -2 Voltage relay
2. After an adjustable Source Loss time delay (factory set at three seconds), Main Breaker "52-M1" or "52-M2" opens.
3. After an adjustable Breaker Open to Breaker Close time delay (factory set at two seconds), the tie breaker "52-T" closes.
4. Critical Loads on the side of the bus that suffered the outage are without power while transitioning ot the altenrate utility source, lasting approximately **five** seconds, which is considered acceptable, and the Tesla battery system is not dispatched.

### C. NORMAL POWER RETURNS ON MAIN 52-M1 OR 52-M2 (AUTOMATIC RETRANSFER – OPEN TRANSITION)

1. Normal voltage is detected by device 27/47-1 or -2 Voltage relay.
2. Auto Retransfer Switch must be in "ON" position.
3. After an adjustable Source Stabilization adjustable time delay (factory set at ten seconds), Tie breaker "52-T" opens.
4. After an adjustable Breaker Open to Breaker Close time delay (factory set at two seconds), Main "52-M1" or "52-M2" closes.
5. Critical Loads on the side of the bus that suffered the outage experience a second power outage while transitioning back to normal that lasts for approximately **two** seconds, which is considered acceptable, and the Tesla battery system is not dispatched.

### D. NORMAL POWER LOST ON BOTH 52-M1 AND 52-M2 (ISLAND MODE WITH AUTOMATIC RETRANSFER AND CLOSED TRANSITION)

1. Initial Conditions:
   - Normal utility voltage is present on one or both Main (52-M1 and/or 52-M2)
   - Breaker 52-BAT is closed, and the Tesla system is charged and ready for operation.
   - The Auto Retransfer Switch must be in "ON" position on the switchgear.
   - The Mode Switch 43SYS on the Island BOS control panel must be in the "AUTO" position.
   - On the Island BOS touchscreen, the "Closed Transition" option box must be checked.
2. Voltage failure is detected on both utility sources at the same time by the 27/47-1 and 27/47-2 voltage relays.
   - Note that this may occur simultaneously, or after the switchgear is operatin on only one utility feeder (one Main breaker has already been opened and the Tie breaker is closed).
3. After an adjustable Source Loss time delay (factory set at **three seconds**), each Main Breaker "52-M1" and "52-M2" opens.

4. Once the switchgear has been completely de-energized according to the PLC, the PLC issues the "Island Mode Active" signal to the Island BOS.
5. After an adjustable "Island Activation Delay" time delay (factory set at **one second**), the PLC executes a Load Shedding scheme to remove any non-critical loads. The following breakers are opened, in order, with a "Load Shedding Operation Delay" time between each breaker opening (factory set at **0.5 seconds**):
    - Breaker 52-2A "MCC01-A Feeder #1"
    - Breaker 52-3A "MCC02-A Feeder #1"
    - Breaker 52-3B "MCC05-A Feeder #1"
    - Breaker 52-6A "MCC01-A Feeder #2"
    - Breaker 52-6B "MCC02-A Feeder #2"
    - Breaker 52-6C "MCC05-A Feeder #2"
6. The PLC will then verify that the following critical load breakers are closed, in order, with a "Load Shedding Operation Delay" time between each breaker opening (factory set at **0.5 seconds**):
    - Breaker 52-1C "RSP-02-2006 Raw Sewage Pump (Future)"
    - Breaker 52-2B "RSP-02-2005 Raw Sewage Pump"
    - Breaker 52-2C "RSP-02-2004 Raw Sewage Pump"
    - Breaker 52-5A "RSP-02-2003 Raw Sewage Pump (Future)"
    - Breaker 52-5B "RSP-02-2002 Raw Sewage Pump"
    - Breaker 52-5C "RSP-02-2001 Raw Sewage Pump"
    - *Note: under normal conditions, all of these breakers should already be closed, thus requiring no breaker operations for a normal load shedding scheme.*
7. The PLC will then close Tie breaker 52T, enabling the Tesla inverters to power critical loads on both sides of the Main-Tie-Main bus while in Island Mode.
8. Once the Load Shedding scheme is complete and the Tie breaker 52-T is closed, the Island BOS makes a Binary signal available for Tesla to read, indicating permission to enter Island Mode.
9. The Tesla inverters are then able to energize the dead bus, and power critical loads. Critical loads have been out of power for approximately ***7* seconds**.
10. Once either one of the two Main utility connections is restored, normal voltage is detected by the PLC by monitoring the coresponding 27/47-1 and 27/47-2 voltage relays.
11. After an adjustable Source Stabilization adjustable time delay (factory set at ten seconds), the PLC sends a "Ready for Closed Transition" signal to the Island BOS.
12. Whichever Main breaker's voltage returns and becomes stable first will be selected to synchronize across, and the PLC will energize the "Synch Select Relay" (25SS-1 or 25SS-2) for the selected source. The 25SS-1 and 25SS-2 relays will be four-pole ice cubes that have the following contact outputs:
    - Bring this Main Breaker's Utility Voltage to the 11U relay (SEL-700G) synch voltage input
    - Enable this Main Breaker's close coil circuit
    - Block the opposite 25SS relay from being energized at the same time
13. The Island BOS then issues the "Synchronize" command to Tesla, which begins monitoring Utility Voltage and Phase Angle measurements via the 11U relay (SEL-700G), correcting its frequency and voltage to obtain synchronization.
14. Once the 11U relay considers Tesla and the selected Main breaker's utility voltages synchronized, the selected breaker will be allowed to close, completing the closed transition back to the utility.

15. Once the selected Main Breaker (52-M1 or 52-M2) closes, the Tesla system will cease discharging, and begin charging as normally scheduled.

**E. NORMAL POWER RETURNS ON MAIN 52-M1 or 52-M2 (MANUAL RETRANSFER – OPEN TRANSITION)**

1. Normal voltage is detected by device 27/47-1 or -2 Voltage relay.
2. Auto Retransfer switch must be in the "OFF" position.
3. Turn the Auo/Man switch to the "MAN" position.
4. After an adjustable Source Stabilization time delay (factor set at ten seconds), Tie breaker "52-T" may be opened via the manual open pushbutton on the touchscreen.
5. After an adjustable Breaker Open to Breaker Close time delay (factory set at two seconds), Main "52-M1" or "52-M2" may be closed via the manual close pushbutton on the touchscreen.
6. Return the Auto/Manual switch to the "AUTO" position to resume normal operations.

**F. NORMAL POWER RETURNS ON MAIN 52-M1 OR 52-M2 (SEMI-AUTOMATIC RETRANSFER – OPEN TRANSITION)**

1. Auto Retransfer Switch must be in the "OFF" position.
2. Normal voltage isdetected by device 27/47-1 or -2 Voltage relay.
3. Retransfer to normal utility main will be suspended as long as the retransfer switch is in the "OFF" position.
4. Turn the retransfrer switch to the "ON" position.
5. After the Source Stabilization delay expires (factory set at ten seconds), Tie breaker "52-T" opens. (If loss of voltage occurs to the existing source during this time, the time delay will be reduced to one (1) second delay and an open transition transfer to the normal power source will occur; the Tie breaker "52-T" will remain closed).
6. After a software adjustable time delay (factory set at two seconds), Main "52-M1" or "52-M2" closes.
7. Return the retransfer switch to the "OFF" position to resume normal semi-automatic operation.

**G. SIMULATION OF NORMAL POWER FAILURE ON MAIN 52-M1 or 52-M2 (TRANSFER TESTING)**

1. Move the "TEST TRANSFER" switch to the "TTM1" or "TTM2" position.
2. After a software adjustable time delay (factory set at three seconds), Main breaker "52-M1" or "52-M2" opens.
3. After a software adjustable time delay (factory set at two seconds), Tie breaker "52-T" closes.
4. To transfer to the normal power source, move the "TEST TRANSFER" switch back to the "NORM" position.
5. The system will transfer back to utility power per above procedures C, D, or E depending on the positino of the retransfer switch.
6. The "TEST TRANSFER" switch is password protected to prevent unauthorized use.

**H. MANUAL OPERATION**

1. Turn the Auto/Man Selector Switch to the "MANUAL" position.
2. Breakers may be operated via touchscreen pushbuttons.
3. Open transition operation is permitted at all times when the Auto/Manual Selector Switch is in the "MANUAL" position.
4. Undervoltage (or phase imbalance) as detected by the respective undervoltage relay 27/47-1 or 27/47-2 will not result in the respective Main breaker opening.

5. The battery breaker 52-BAT can be manually closed with the bus energized and the Tesla system energizing the non-bus side of the breaker only when the two sources are synchronized according to the 11U relay (SEL-700G).

## INTERLOCKING NOTES

The following notes describe safety interlocks built into the switchgear control system:

1. When the Auto/Man selector Switch is in the "MANUAL" position, breaker control push buttons are operable and protective interlocks including non-paralleling, non-reclosure onto a fault, and voltage protection remain intact. Breakers will not close automatically. Normal power and tie breakers will not close unless voltage is available on the line side. When a breaker is in the "TEST" position, interlocks are bypassed. Auto/Man Selector Switch should be left in "MANUAL" position when switchgear is to be serviced or automatic operation is not desired.

2. Overcurrent Trip Switches (SDE) on the breakers prevent breaker reclosure onto a fault or overcurrent. Place the Auto/Man Selector Switch in the "MANUAL" position before resetting the SDE. When the PLC detects an overcurrent trip signal in the "AUTO" mode, it will lockout normal power breakers. The breakers will remain locked out even if the SDE is reset, and until the Auto/Man Selector Switch is placed into the "MANUAL" position. This is to prevent automatic reclosure into a fault while the operator is resetting the overcurrent trip device located on the breaker. The Auto/Man Selector Switch can then be placed in the "AUTO" position. The "AUTO FAIL" light indicates a failure condition and will remain on until the SDE is reset, and the Auto/Man selector switch has been placed in the "MANUAL" position.

3. Truck Operated Cell Switches (TOC) located in the breaker cells bypass the interlock circuits when one or more breakers are in the "TEST" or "DISCONNECTED" position. This will allow the other breakers to continue Manual mode operation. The Auto/Man Selector Switch should be left in the "MANUAL" position with breaker(s) removed. The "AUTO FAIL" light will illuminate when "AUTO" mode is selected and any one or more breakers is in the "TEST" or "DISCONNECTED" position.

4. In the event of PLC failure, electrical interlocking outside the PLC program utilizes breaker auxiliary contacts to logically prevent all three breakers from being closed at the same time (forces open transition transfers).

5. Open/Close pushbuttons on the circuit breaker should not be used while in "AUTO" mode. Doing so will result in "AUTO FAIL" condition and possible tripping of circuit breakers.

6. Racking all three breakers to the test position will allow the operator to return the system to normal and test out transfer operations without actually powering loads.

7. All three source breakers (52-M1, 52-M2, and 52-BAT) as well as the Tie breaker 52-T are all interlocked outside of the PLC such that the Island Controller 11U relay (SEL-700G) can prevent any breaker from closing. The 11U relay logic will prevent the following adverse conditions from happening:
    1. Closing more than two Source breakers at the same time
    2. Closing the Tie breaker 52-T with both sides energized
    3. Closing the 52-BAT breaker out of sync with voltage on both sides
    4. Closing any breaker into a known fault