Documenting and Programming a Complex Sequence of Operation

Presented
By

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Water Treatment Plant
Path to Success

Why?

Single Line

Sequence

Controls

Structure
The Single Line

Emergency Power System
Sequence of Operation

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Sequence of Operation

B. General automatic mode of operation:

1. Under-voltage and under-frequency relays located in the ORP plant switchgear SG-N-1 and SG-N-2 are used to detect power failure and signal the PLC to start the generators. Upon confirmation of utility power failure, the PLC evaluates the system’s status and initiates a power transfer from utility power to standby power. All generators in standby mode will automatically start in sequence. Power failure can also be simulated by selecting “System Test” from the front of the Master Control Section.

2. Upon confirmation that utility power has returned for a specified time, the PLC shall initiate a transfer from standby power to utility power.
Nine (9) Common Configurations

FIGURE 100

FIGURE 200

FIGURE 300

FIGURE 400

FIGURE 500

FIGURE 600

FIGURE 700

FIGURE 800

FIGURE 900
Type 900
Some “what ifs” to think about

- Generator failure
  - Out of service
  - Does not start
  - Fails after it was running
  - Becomes overloaded
  - Pre alarm
- Breaker failure
  - Fail to open
  - Fail to close
- Control system failure
This is the way I was taught to write a sequence

Section 2 Modes of Operation

2.1 Emergency Mode

2.1.1 Response to Loss of Utility
The loss of utility causes the Engine Start Delay timer in the PLC to start. If this timer expires, then the following sequence will occur:
1. The Utility Breaker (52U) opens.
2. The priority 2 and 3 feeder breakers open.
3. The generators start.
4. The first generator that has stable voltage and frequency closes its breaker.
5. Tie Breaker (52T) closes.
6. The other generator synchronizes to the bus. When synchronized, its circuit breaker closes.
7. The priority 2 and 3 feeder breakers close.

2.1.2 Response when Utility Returns
When the utility returns, the Utility Stable timer in the PLC starts.
When this timer expires, the following sequence occurs:
3. The generators soft (ramp) unload.
4. When the generators reach their unloaded setpoint, 52T and the generator breakers open.
5. The generators shut down after completing a cool down cycle.

2.2 Isolate Mode
Isolate mode is used to manually initiate a transfer to generator power. This can be used to test the system or in anticipation of a potential power failure.

2.2.1 Start – Transfer to Generator
Momentarily touching the isolate mode start push-button on the touch-screen starts the following sequence:

If open transfer mode is selected:
1. The generators start.
2. The first generator that has stable voltage and frequency closes its breaker.
3. The other generator synchronizes to the bus. When synchronized, its circuit breaker closes.

NOTE: If the second generator fails to start or go on-line, the operator can depress the Isolate GOL Bypass push-button and the sequence will continue with one generator.
There had to be a better way
How every system works
Simple Example
The System
32 Possible States

|   | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 152_M | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 152_1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| T1/T2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 252_1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 252_M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
A sequence is a transition from current state to new state
Can One Document do it All?

- Submittal Sequence of operation
- PLC Programming instructions
- FAT (factory acceptance test) document
- SAT (site acceptance test)
- Final O&M manual
How to describe the transition
What if something goes wrong?

<table>
<thead>
<tr>
<th>Step</th>
<th>Event</th>
<th>System Response</th>
<th>Operator Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Utility A power returns before Utility A Failure and Utility B Failure timers expire</td>
<td>Bus A remains on utility A. Bus B loads transfer to generator power (Seq. 601) or utility A power (Seq. 602).</td>
<td>No operator action required.</td>
</tr>
<tr>
<td>B</td>
<td>Utility B power returns before Utility A Failure and Utility B Failure timers expire</td>
<td>Bus B remains on utility B. Bus A loads transfer to generator power (Seq. 601) or utility B power (Seq. 602).</td>
<td>No operator action required.</td>
</tr>
<tr>
<td>C</td>
<td>Utility breaker UA fails to open</td>
<td>Utility A Remains Failed, Utility B Remains Failed: Bus A is without power. Generator main breaker GMA does not close. After the required generators are online, generator main breaker GMB closes.</td>
<td>Option #1: Reset the Fail To Open alarm. System retries to open utility breaker UA. When breaker opens, transfer automatically continues. Option #2: Manually open utility breaker UA. Transfer automatically continues if system is in Auto. 1. Place system in Manual 2. Manually open utility breaker 1U. 3. Manually open utility breaker 2U.</td>
</tr>
</tbody>
</table>
The “sequence” is a series of charts
PLC Programming

- Very easy to program and troubleshoot the system behavior
  - Based on breaker position
    - System does not get "confused"
  - We can see the history
- Very easy to modify a sequence
  - Only thing effected is that one sub routine
Operator Interaction with System

- **Stuff on the doors**
  - HMI – Human Machine Interface
    - Touchscreen
  - Meters
    - Analog
    - Digital
    - Power quality
  - Switches
    - Control
  - Remote control
  - Remote monitoring
Easy to operate
Generator Controls
What Just Happened?
Water Treatment Plant
Path to Success

Why?

Single Line

Sequence

Controls

Structure
The “sequence” is a series of charts
Controls
Structure – Power Section
The sentence that......

Submit complete documented PLC ladder logic program to implement the generator start, paralleling and synchronization, load shedding, source transfer, etc., as described herein and as shown on the drawings.