Watts Bar Nuclear Plant

Degraded Grid Voltage Protection

April 24, 2014

Agenda

- Objectives
- History
- Conformance with NRC Guidance PSB-1
- Response to Supplemental Safety Evaluation Report 22,
  Open Item 30
- Additional Degraded Voltage Protection Scenarios
- Conclusions

Objective

- To describe degraded voltage protection system installed at Watts Bar Nuclear Plant
- To provide information on TVA's resolution for Supplemental Safety Evaluation Report 22, Open Item 30 for Watts Bar Unit 2
- To provide information regarding case studies that address other degraded voltage scenarios
- To obtain alignment on actions needed to resolve Open Item

History – Industry Events

- Millstone 1st Event – July 5, 1976

  Adverse effects on Class 1E loads caused by sustained low grid voltage
  - Not detected by LOV relays that were generally 70% (at that time)

- Millstone 2nd Event – July 21, 1976

  Improper voltage protection logic can itself cause adverse effects on Class 1E systems and loads
  - Spurious load shedding of loads from EDGs
  - Spurious LOOP Due to normal motor starting transients

- Arkansas Nuclear One Event – September 16, 1978

  Degraded voltage conditions can exist on Class 1E buses even with normal grid voltage
  - Deficiencies in design between grid and Class 1E buses
  - Starting transients during LOCA sequencing not considered in circuit design

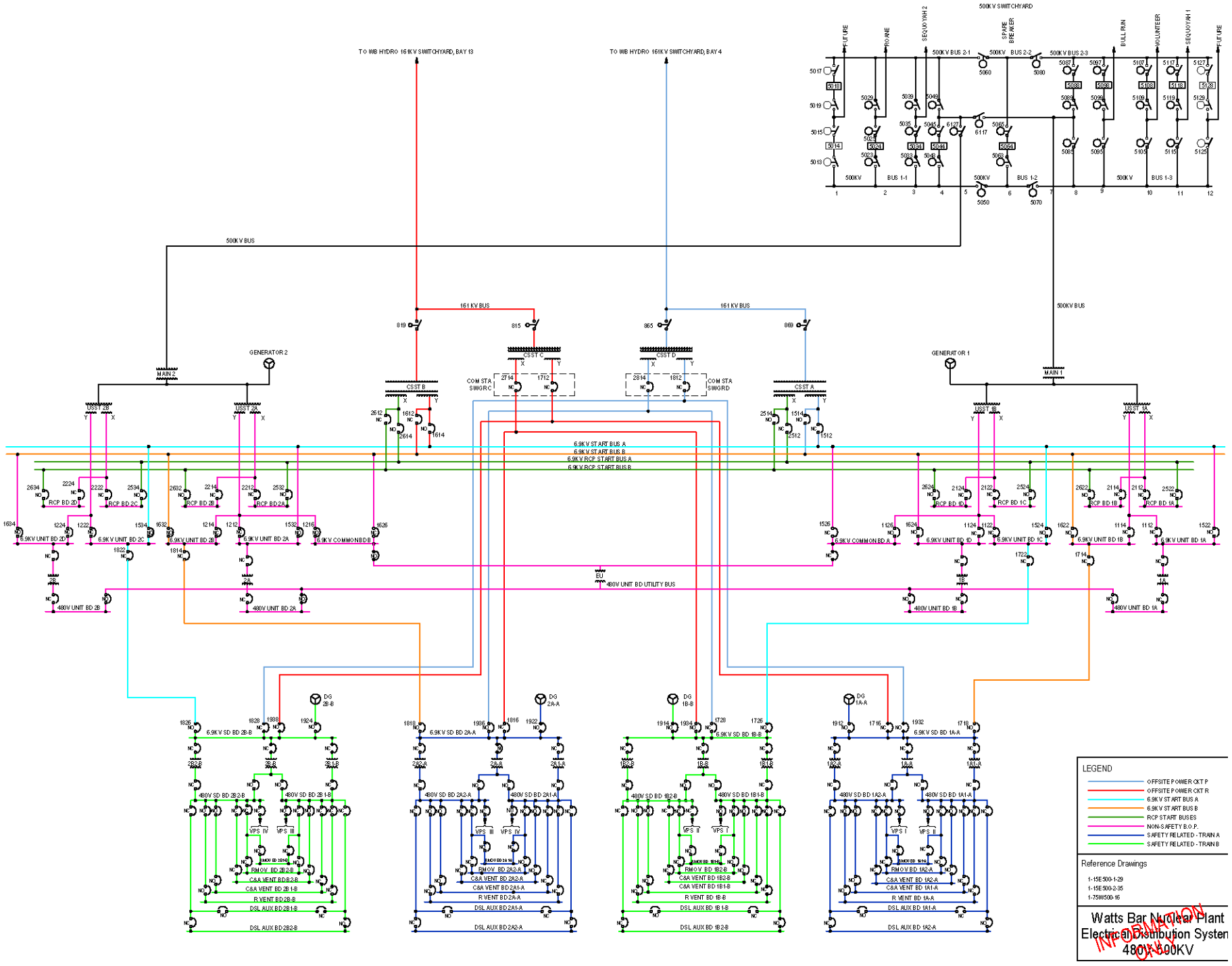
History – Regulatory Guidance

- 1977 NRC letter
- Information Notice 79-04,
  - “Degradation of Engineered Safety Features,” on February 14, 1979
- Generic Letter (GL) 79-36,
  - “Adequacy Of Station Electric Distribution Systems Voltages on August 8, 1979”
- Branch Technical Specification PSB-1,
  - “Adequacy of Station Electric Distribution System Voltages (PSB-1),” July1981
  - PSB-1 is a compendium and clarification of preceding guidance

History – Implementation at Watts Bar Nuclear Plant

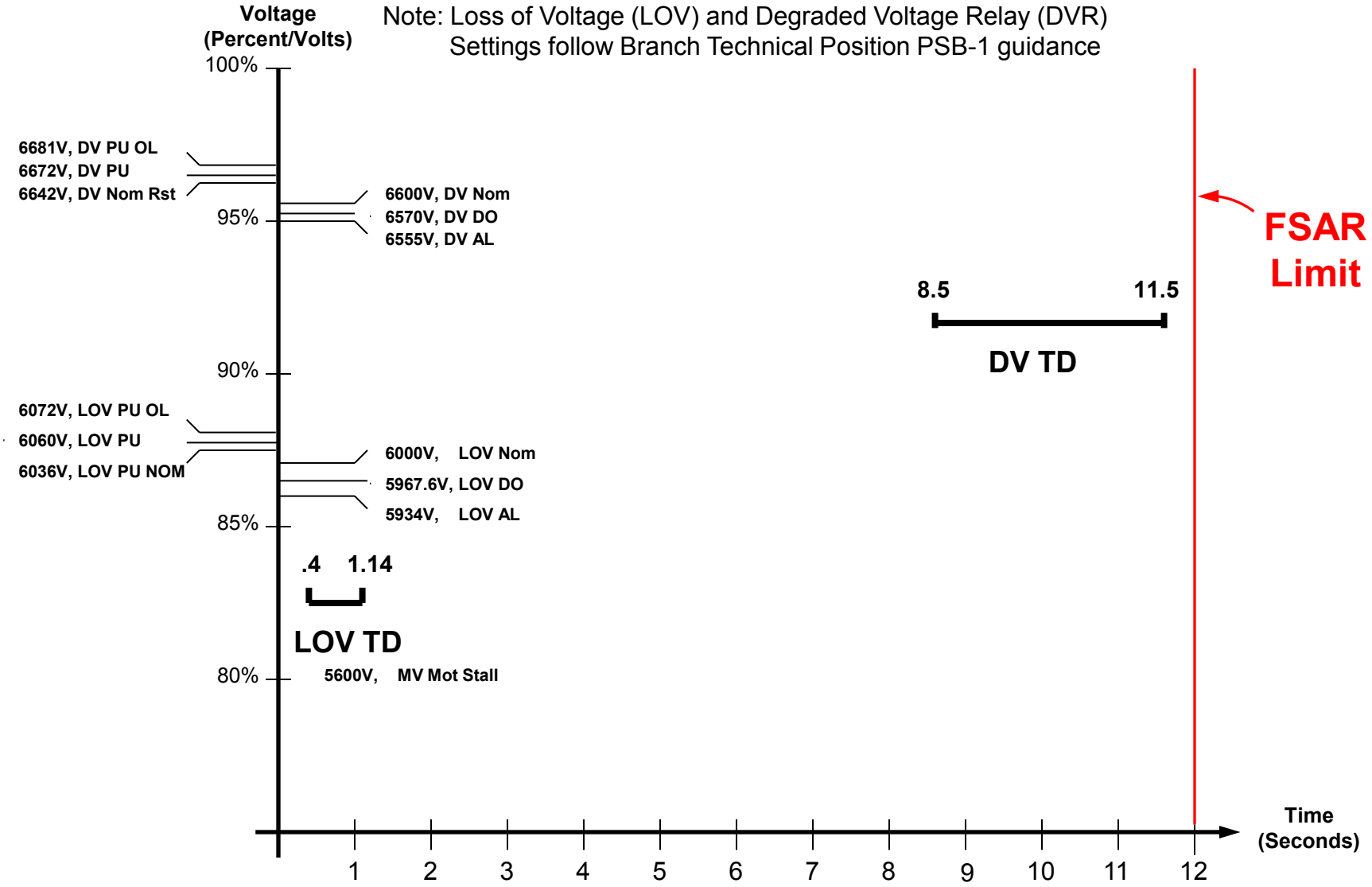
TVA installed degraded voltage protection to support the operation of Watts Bar 1 (second level of protection referred to in PSB-1)

- Same protective scheme that will support operation of Watts Bar 2
- Voltage relays (sensors) at Class IE buses (6.9 kV Shutdown Boards)
- Two out of three trip logic
- Singular time delay
  - Longer than motor starting transient
  - Less than accident analysis limit for transfer to onsite power
- Control room annunciation
- Initiates transfer to onsite power supply


500KV SWITCHYARD
FUTURE
ROANE
SEQUOYAH 2
SPARE BREAKER
BULL RUN
VOLUNTEER
SEQUOYAH 1
FUTURE
500KV BUS 2-1
500KV BUS 2-2
500KV BUS 2-3
500KV BUS 1-1
500KV BUS 1-2
500KV BUS 1-3
TO WB HYDRO 161KV SWITCHYARD, BAY 13
TO WB HYDRO 161KV SWITCHYARD, BAY 4
500KV BUS
161 KV BUS
161 KV BUS
500KV BUS
MAIN 2
MAIN 1
GENERATOR 2
GENERATOR 1
CSST B
CSST C
CSST D
CSST A
COM ST A SWGR C
COM ST A SWGR D
USST 2B
USST 2A
USST 1B
USST 1A
6.9KV START BUS A
6.9KV START BUS B
6.9KV RCP START BUS A
6.9KV RCP START BUS B
RCP BD 2D
RCP BD 2C
RCP BD 2B
RCP BD 2A
RCP BD 1D
RCP BD 1C
RCP BD 1B
RCP BD 1A
6.9KV UNIT BD 2D
6.9KV UNIT BD 2C
6.9KV UNIT BD 2B
6.9KV UNIT BD 2A
6.9KV COMMON BD B
6.9KV COMMON BD A
6.9KV UNIT BD 1D
6.9KV UNIT BD 1C
6.9KV UNIT BD 1B
6.9KV UNIT BD 1A
EU
480V UNIT BD UTILITY BUS
480V UNIT BD 2B
480V UNIT BD 2A
480V UNIT BD 1B
480V UNIT BD 1A
DG 2B-B
DG 2A-A
DG 1B-B
DG 1A-A
6.9KV SD BD 2B-B
6.9KV SD BD 2A-A
6.9KV SD BD 1B-B
6.9KV SD BD 1A-A
480V SD BD 2B2-B
480V SD BD 2B1-B
480V SD BD 2A2-A
480V SD BD 2A1-A
480V SD BD 1B2-B
480V SD BD 1B1-B
480V SD BD 1A2-A
480V SD BD 1A1-A
VPS IV
VPS III
VPS II
VPS I
RMOV BD 2B2-B
RMOV BD 2A2-A
RMOV BD 1B2-B
RMOV BD 1A2-A
C&A VENT BD 2B2-B
C&A VENT BD 2B1-B
C&A VENT BD 2A2-A
C&A VENT BD 2A1-A
C&A VENT BD 1B2-B
C&A VENT BD 1B1-B
C&A VENT BD 1A2-A
C&A VENT BD 1A1-A
R VENT BD 2B-B
R VENT BD 2A-A
R VENT BD 1B-B
R VENT BD 1A-A
DSL AUX BD 2B2-B
DSL AUX BD 2B1-B
DSL AUX BD 2A2-A
DSL AUX BD 2A1-A
DSL AUX BD 1B2-B
DSL AUX BD 1B1-B
DSL AUX BD 1A2-A
DSL AUX BD 1A1-A
LEGEND
OFFSITE POWER CKT P
OFFSITE POWER CKT R
6.9KV START BUS A
6.9KV START BUS B
RCP START BUSES
NON-SAFETY B.O.P.
SAFETY RELATED - TRAIN A
SAFETY RELATED - TRAIN B
Reference Drawings
1-15E500-1-29
1-15E500-2-35
1-75W500-16
Watts Bar Nuclear Plant
Electrical Distribution System
480V & 500KV
INFORMATION ONLY

TVA Analysis – WBN LOV and DVR Relay Settings

Note: Loss of Voltage (LOV) and Degraded Voltage Relay (DVR) Settings follow Branch Technical Position PSB-1 guidance



WBN Degraded Voltage Protection Conformance with PSB-1

- PSB-1 Technical Position B.1.a:
  - Watts Bar selection of undervoltage and time delay setpoints was determined from analysis of voltage requirements of Class 1E loads at all onsite system levels
- PSB-1 Technical Position B.1.b.1 and B.1.b.2
  - Watts Bar degraded voltage protection includes single time delay – is a more restrictive design than required by guidance
  - Time delay is **8.5** seconds (Safety Limit lower value)
  - Time delay provides both alarm and separation functions
  - Time delay is greater than motor starting transient
  - Watts Bar degraded voltage protection logic does not include SIAS signal input:
    - If grid voltage is degraded, time delay will transfer to onsite power
    - Any subsequent design basis accident would be powered directly and immediately from onsite power source
  - Connected loads demonstrated to not be damaged during time delay

WBN Degraded Voltage Protection Conformance with PSB-1

- PSB-1 Technical Position B.1.c
  - Degraded voltage relays conform to Class 1E and redundant design elements B.1.c.1 -6

- PSB-1 Technical Position B.1.d

Technical Specification LCO 3.3.5 – Loss of Power (LOP) Diesel Generator (DG) Start Instrumentation

✓ Function 2 – 6.9 kV Emergency Bus Undervoltage (Degraded Voltage)

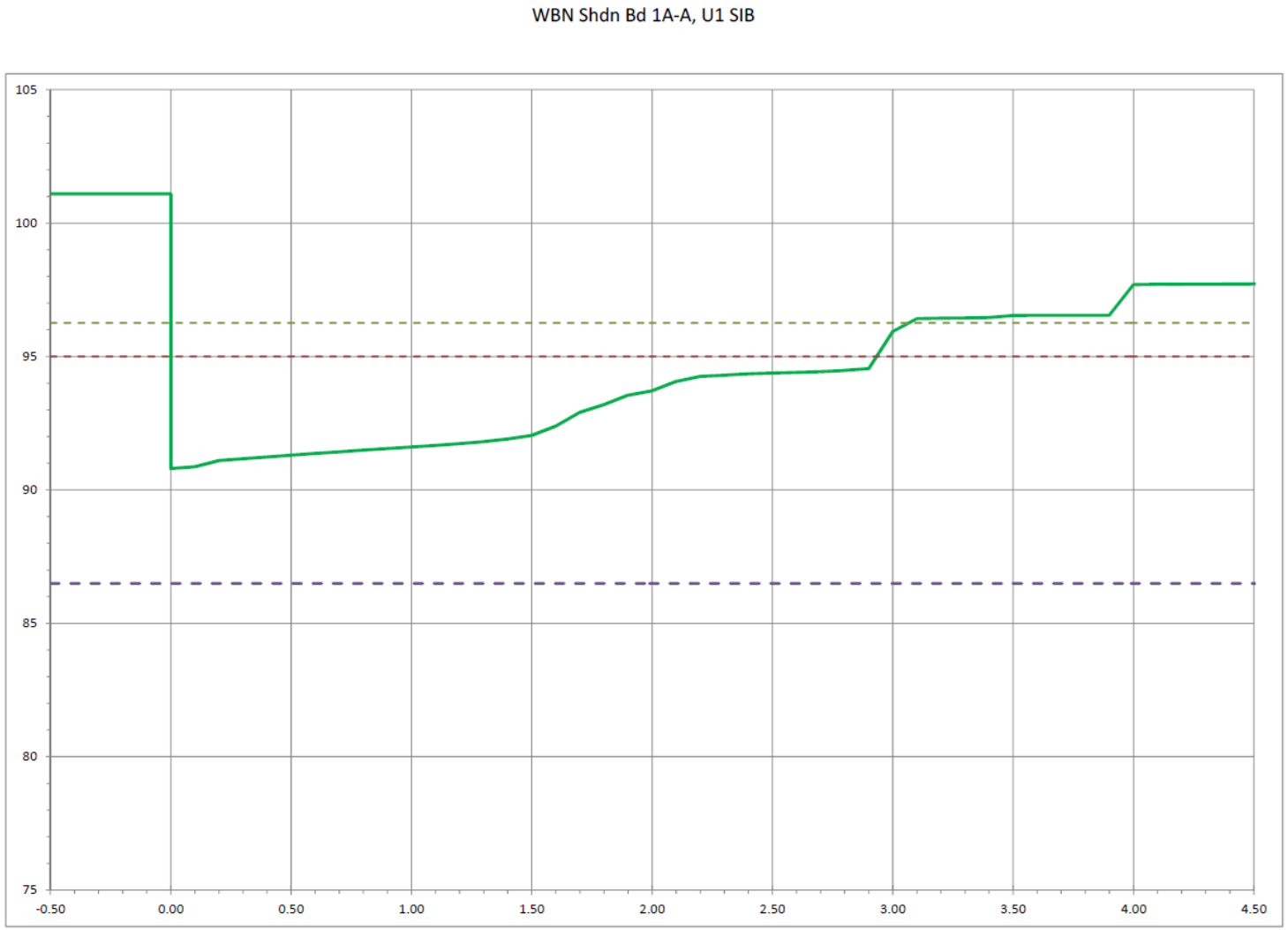
	Trip Setpoint	**Allowable Value**
➢ Bus Undervoltage	≥ 6593.4 V and ≤ 6606.6 V	≥ 6570 V
➢ Time Delay	≥ 9.73 sec and ≤ 10.27 sec	≥ 9.42 sec and ≤ 10.49 sec

- Technical Specification surveillance requirements
  - SR 3.3.5.1; SR 3.3.5.2; and 3.3.5.3

WBN Degraded Voltage Protection Conformance with PSB-1

- PSB-1 Technical Position B.2
  - Watts Bar's degraded protection logic does not cause loads to be shed from the diesel generators
- PSB-1 Technical Position B.3
  - Station connected to a qualified grid
  - Demonstrates offsite sources are qualified per GDC-17 requirements
  - Voltage drop of the grid during a DBA is ≤ 9kV at the high side of the CSSTs.
  - CSST tap changers are functioning properly.
  - All 6.9kV Shutdown Boards are aligned to CSST A (worst-case alignment).
  - 1E buses remain connected to offsite power and 1E components have adequate voltage for starting and running within analyzed time limits.
  - See Next Slide
- PSB-1 Technical Position B.4
  - Testing was performed during startup of WBN Unit 1

Minimum Qualified Grid Case (GDC-17 Offsite Power Analysis)



Response to Supplemental Safety Evaluation Report, Open Item 30

- Open Item 30:

  TVA should confirm that all other safety-related equipment (in addition to the Class 1E motors) will have adequate starting and running voltage at the most limiting safety related components (such as motor operated valves, contactors, solenoid valves or relays) at the degraded voltage relay setpoint dropout setting. TVA should also confirm that the final Technical Specifications are properly derived from these analytical values for the degraded voltage settings. (Section 8.3.1.2)

- Essential Elements of Open Item
  - Confirm adequate performance for running equipment
  - Confirm adequate starting performance
  - Confirm Technical specification adequacy

Response to SSER Open Item 30

- Steady-state loading conditions (running load):
  - The DVR dropout setting was previously established using TVA/industry setpoint methodology to confirm that all safety-related equipment (in addition to the Class 1E motors) have adequate running voltage at the most limiting components (such as MOVs, contactors, solenoid valves and relays)
  - These studies were carried out by maximizing running loads on the Class 1E distribution system (bounding combination of safety system loads), with the voltage at 6.9-kV Class 1E buses (monitored by the DVRs) at the DVR dropout setting
  - No credit was taken for any equipment operation (such as Load Tap Changers) upstream of the 6.9-kV Class 1E buses.
  - The technical specifications were derived from the analytical values for the DVR dropout and time delay settings.

Response to SSER Open Item 30

- Transient loading conditions (starting load):
  - Because voltage monitoring relays are not suited for protection against inadequate motor starting voltage, TVA performed a sensitivity study to assess the potential impact of considering starting transients on existing DVR setpoints.
  - STUDY-EEB-WBN-12-001 was performed to address adequacy of previously established DVR settings for motor starting voltage
    - The motor-starting studies were based on the DVR dropout and time delay analytical limits
    - The motor-starting studies did not credit any equipment operation (such as LTC transformers) upstream of the 6.9-kV Class 1E buses

TVA Sensitivity Study for SSER Open Item 30

STUDY-EEB-WBN-12-001

- Purpose was to study the impact on the DVR setpoint or plant response if the existing TVA DVR setpoint methodology was changed to include motor starting voltage as a basis for establishing DVR dropout setting.

- The analytical approach used was based on the fact that for any Class 1E motor starting event (single motor, group of motors, or DBA sequence) the voltage at the DVR monitored bus can only respond in one of three ways:

  1. The voltage never drops below the DVR dropout setting (i.e. DVR never actuates)

  2. The voltage drops below the DVR dropout and never recovers above reset within the DVR time delay (i.e. DVR actuates and times out, transfers loads to the DGs)

  3. The voltage drops below the DVR dropout but recovers above reset within the DVR time delay (i.e. DVR actuates but does not time out, loads remain on offsite power)

- Analyses were performed for each of these situations. These analyses bound any possible voltage outcome at the Class 1E buses when starting any Class 1E motor(s) required for any scenario.

TVA Sensitivity Study for SSER Open Item 30

STUDY-EEB-WBN-12-001

- Provided in submittal dated June 7, 2012
- Starting Voltage Analysis (for Scenario 1)
- Protective Device Analysis (for Scenario 2)
- Bounding Voltage Recovery Analysis (for Scenario 3)

Starting Voltage Analysis (Scenario 1)

- The analytical approach chosen demonstrates acceptability of voltages during any motor starting scenario where the DVR monitored bus never drops below the DVR dropout setting.

- Study also validates that Class 1E components will operate anytime voltage recovers above the DVR dropout
  - Voltage at the DVR monitored bus set at the DVR dropout analytical limit using a fixed voltage
  - This simple technique provides conservative bounding voltages for all 1E loads for all times after event initiation
  - No credit taken for LTCs or any other voltage impact upstream

- Two cases analyzed:
  - DBA load initiation events
  - Individual (manual) motor starting (e.g. required post-event motor starts)

- Conclusion:
  - Validates that all Class 1E motors will start when the Class 1E bus voltage is at or above the DVR dropout setpoint.

Protective Device Analysis (Scenario 2)

- Validates that for the period that DVR relay is timing out, Class 1E components:
  - Will not be damaged if they stall
  - Will not be locked out by a protective device (including control power fuses)
- Validates that the required Class 1E components will successfully start once connected to the DGs.

Bounding Voltage Recovery Analysis (Scenario 3)

- Station connected to a degraded grid
  - Grid voltage is at 100%.
  - CSST tap changers are not functional.
  - Grid capability is reduced so that at T=0 sec. the voltage is below the LOV drop out but above the Medium Voltage Motor stall voltage (they accelerate).
  - All Shutdown Boards are aligned normally.
  - This case is most representative of a realistic degraded grid condition.
- Conclusion:

  During a DBA
  - If the LOV relay times out, Safety Related busses disconnect from off site power and transfer to the DGs
    - Safety Related components have adequate voltage for starting and running within analyzed time limits.
  - If the LOV relay does not time out, Safety Related busses remain connected to off site power
    - SR components have adequate voltage for starting and running within analyzed time limits.

Additional Case Studies

- DVR at Dropout Prior to Design Basis Accident
- Grid Capability at DVR Reset Threshold

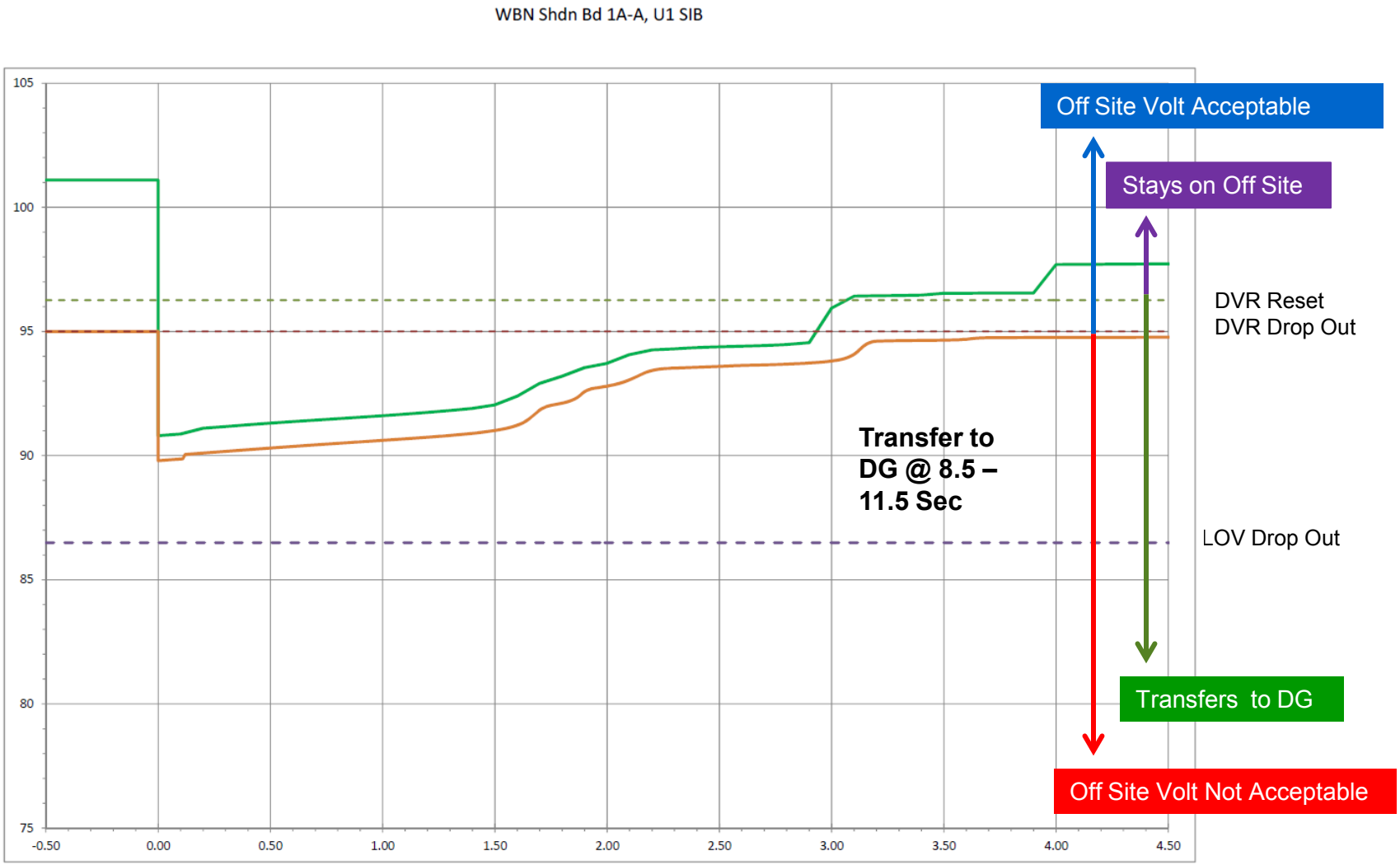
DVR at Dropout Prior to DBA (Does Not Reset)

- Station connected to a degraded grid
  - Grid voltage results in voltage at DVR drop out value (6555V) prior to DBA.
  - CSST load tap changers are assumed not functioning.
  - Fixed voltage source was modeled at the station switchyard
  - All Shutdown Boards are assumed aligned normally.

Note: Without the load tap changer, this case can not be successfully recovered by offsite power since the post-event loading is greater than the pre-event loading

- Conclusion:
  - Class 1E buses disconnect from off site power and transfer to the DGs
  - Based on previous analysis (protective device analysis), Class 1E components have adequate voltage for starting and running within analyzed time limits

DVR at Dropout Prior to DBA
DVR Does Not Reset – 1E Buses Transfer to DGs



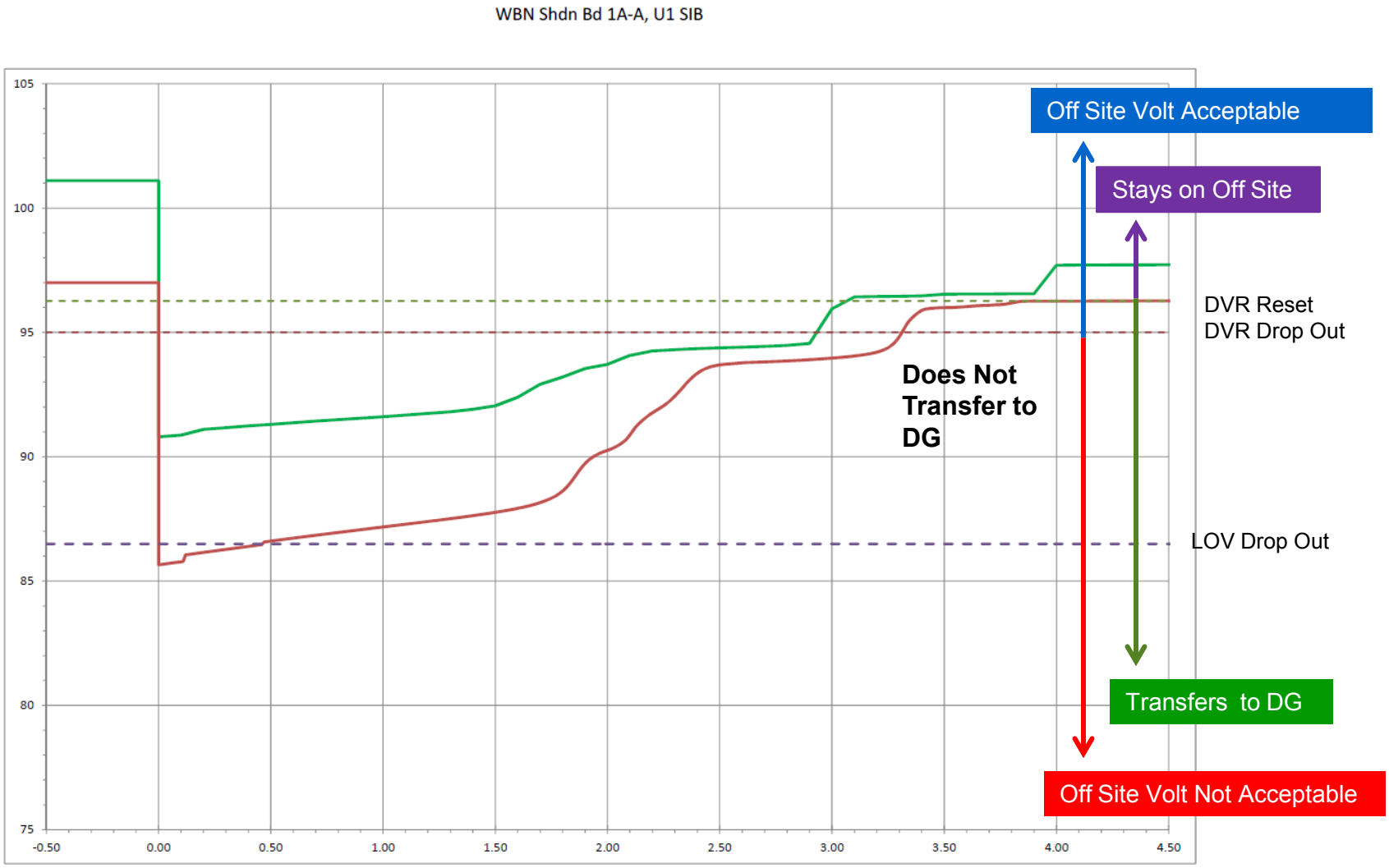
Grid Capability at DVR Reset Threshold

- Station connected to a degraded grid
  - Grid capability (voltage level and strength) results in initial voltage drop that barely recovers above LOV setpoint prior to 0.5 sec and then recovers to (exactly) the DVR reset value prior to 8.5 sec.
  - CSST load tap changers are not functioning
  - Fixed voltage source was modeled at the station switchyard
  - All Shutdown Boards are aligned normally

  Note: This case, while not representative of any actual postulated grid failures, results in the worst conceivable grid that allows Class 1E buses to remain on offsite power
- Conclusion:
  - This case demonstrates that any conceivable voltage transient caused by motor starting, even at the threshold of LOV timeout AND DVR timeout, will result in recovery of voltage (DVR reset or above) within 4 seconds.
  - Recovery time not significantly different than that shown for offsite power analysis (minimum qualified grid)

Grid Capability at Degraded Voltage Reset Threshold

Worst Possible Grid that Allows Adequate Recovery of Voltage



Overall Conclusion for Additional Case Studies

For WBN voltage protection setpoints and design, during a DBA:

- If the LOV relay times out
  - Class 1E buses disconnect from offsite power and transfer to the DGs
  - Based on previous analysis, Class 1E components have adequate voltage for starting and running within analyzed time limits
- If the LOV relay does not time out, then either:
  - The DVR times out
    - Class 1E buses disconnect from off site power and transfer to the DGs
    - Based on previous analyses, Class 1E components have adequate voltage for starting and running within analyzed time limits

  OR
  - The DVR does not time out
    - Class 1E buses remain connected to off site power
    - Based on previous analyses, Class 1E components have adequate voltage for starting and running within analyzed time limits

Conclusions and Summary

- Watts Bar followed industry and NRC guidance in the development, design, and settings of the degraded voltage relay scheme.
- Watts Bars offsite power analysis demonstrates compliance with GDC-17 requirements.
- The degraded voltage relay scheme ensures protection of safety related motors and components
- The Watts Bar DVR scheme being reviewed for U2 operation is the same as that licensed for U1 operation.

Conclusions and Summary

- Due to the voltage protection system and auxiliary power system design at Watts Bar the most likely outcome of any motor starting event including a DBA sequence is the voltage may decrease as low as the LOV relay setpoint but will still recover above DVR reset well within the DVR timeout.
- For any cases that do not recover above reset, either the DVR or LOV time delay settings allow successful transfer to the onsite power supply with all required Class 1E loads achieving adequate voltage with required time periods.
- No revision to degraded voltage relay setpoints required