

MANUFACTURING INSPECTION

POWER ELECTRONICS STAFFORD, REDHILL, UK

DECEMBER 17, 2019

Prepared for: Natural Resources Canada and NALCOR Energy

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Quality Assurance Statement

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1. GENERAL

On December 17th, the Independent Engineer (IE), Argirov Engineering Inc (AEI), together with Nalcor representatives, participated in GE factory visit in Redhill, UK. This GE "Grid Automation" manufacturing facility is in the process of developing and testing software for control and protection of the Labrador Island Link (LIL) HVDC.

IE visited the plant to discuss the work progress and schedule for development, rollout and site commissioning of the LCP HVDC Control, Protections and HMI software (S/W). Other discussion topics were the work process, resourcing, milestones achieved to date, deficiencies and anticipated time frame for integrated system tests (IST), factory system tests (FST), design and rollout of Stage F of software and factory acceptance testing (FAT).

ATTENDEES

IE: Nik Argirov and Vlad Kahle
LCP: Rosanne Williams and Snehal Parmar
GE: Danish Mumtaz
Amplitude: Matt Gnad (part time)

2. AGENDA

2.1 Safety review and orientation.

2.2 Purpose of the IE and NALCOR visit:

- Communicate adverse impacts of further Project delays.
- Fact finding and analysis of questions raised in Dec. 5/6, 2019 Project Report by Amplitude (ITP).
- Confirm test and delivery timelines.
- Discuss current Issues.
- Reconfirm the plan for Completion of Bi-Pole software.

2.3 Wrap-up and closeout.

3. MEETING

3.1 **Safety**: since this was a repeat visit to the facility, safety orientation was abbreviated.

3.2 **IE Notes**

3.2.1 Project Delays Impact:

IE and NALCOR reiterated the importance of timely delivery of the S/W and that there would be negative outcomes associated with further delays. Besides the requirement to close out the Project and comply with contractual obligations, LIL availability is critical to fully commission the Muskrat Falls generation facility (MF). GE was advised that three MF units plan be commissioned by May 2020 and it is expected that software development for Stage F will be completed by then.

3.2.2 Definitions:

GE's Software Testing Process: Integrated system test (IST) is followed by factory system test (FST). That in turn is followed by factory acceptance tests (FAT).

Regression Testing: Software (S/W) testing to confirm that recent program or code change has not affected existing features. Typically, regression testing is done after new feature is added to S/W or defects were fixed.

Scope: FST1 stage primarily covers protections, operational sequencing and Pole 2 control lane changeover tests. FST2 focuses on control functions. Stage F consists of delivering the final functionality features, final bug fixes, grid control functions and review / functional confirmation of equipment Protection coordination.

3.2.3 Dec. 5/6 ITP Report- Project Plan:

Dec. 13- Release Build IST
Dec.19 - FST1 completion (CER3B)
Dec. 20- FST1 Regression Testing
Dec. 20- Commence FST2 development
Jan. 6 & 7- FST2 Regression Testing
Jan. 8- FST2 completion (CER4)
Jan. 8- Commence FAT
Jan. 19- FAT completion
Jan. 20- Engage Bipole Development Team on Stage F
March 20- Complete Stage F design and integration and implementation
April 20- Complete Stage F IST (Integrated System Tests)
May 20- Complete Stage F FST (Factory System Tests)
June 9- Complete Stage F FAT (Factory Acceptance Tests)

IE Findings:

- a) *Release of IST has been moved to Dec. 19-20 and it may slip into the New Year. More information from GE is expected by end of the week of Dec. 20th. (Post meeting note: IE did not receive an update at the time of Factory Visit report writing)*
- b) *GE advises the FST1 Regression Testing will also slip; new date is not yet available.*
- c) *Commencement of Stage F development is contingent on completion of Stages A to E. Therefore, realistic start date for Stage F design work and Project delivery timeline cannot be determined at this time.*
- d) *2-week allowance for Stage F FAT appears realistic; per the above start date remains a moving target.*
- e) *ITP (independent third party) report by Amplitude recommends complete set of FST be completed before initiating the FAT phase (refer to the above S/W definitions).*
- f) *There appears to be no time allowance for bug fixes between IST, FST and FAT.*
- g) *IE noted there is no allowance for full regression testing of the complete package of FST1, FST2 and Stage F. GE explains that due to the minimum of 4-week time requirement they do not plan to carry out regression testing of the completed system. Instead, they propose to rely on rigorous FST carried out upon completion of each stage.*

3.2.4 Project Progress

- Stated primary issue for schedule slippage is use of non-standard software, i.e. the Control and Protections S/W is being developed from the ground up. Other challenges are posed by very detailed 'user' defined performance requirements that necessitate adherence to rigid fail / pass criteria. There is also added functionality required for operating the Transition Compounds.

- Configuring individual switching sequences is not an issue. Transition from one sequence to another is experiencing problems that are currently being addressed. Some of the issues are related to incorrectly programmed interlocks.
- Stage F controls are not available in the GE S/W library and have to be developed from scratch.
- Cable switching and operation in overload mode are not major issues.
- Bugs are categorized by importance to ensure that high and medium priority bugs are corrected before proceeding to the next stage. There is potential increase in number of bugs whose correction will be deferred to Stage F. It was noted that the count of unresolved bugs is not decreasing as previously planned.
- (Unspecified) Protection failures have been experienced in the test mode.
- Lane changeover is functional, but indication is not properly displayed on the HMI's.

IE Findings:

- a) *Decision to develop unique software for LIL HVDC has been made at early stages of the Project and it cannot realistically be revisited at this late stage.*
- b) *It is not apparent why detailed 'user' requirements present a challenge.*
- c) *No information was given on quantitative impact of Transition Compounds software on the development time-lines.*
- d) *Number of outstanding bugs that will be identified / remedied at later stages presents an unknown risk to the Project schedule and overall quality of delivered S/W package.*
- e) *If not fully addressed prior to the rollout, Protection and lane changeover indication issues would have significant impact on reliability.*

3.2.5 Resourcing

- The challenges are to get resources with skills in both computer coding and HVDC technology. That said, GE reports an improvement in performance as the Project progresses.
- Potentially there are more resources available on contract basis.
- Vacation's impact on key staff availability is being minimized by staggering the staff time off.
- NALCOR monitors are on site full time and Amplitude/Systematic, part time. Project.

IE Findings:

- a) *Every effort should be made to secure S/W designers with expertise in HVDC technology / utility industry.*
- b) *Addition of NALCOR and Amplitude Project monitors improves QA and reporting on development work progress.*

3.2.6 Assessment by Independent Third Party (ITP)

- ITP will authorize the end of FST and FAT.
- There is an improvement in development and testing as the developers acquire more knowledge and are more focused on the electric energy delivery that is the final functionality of the S/W,
- There is an appreciable risk of further delays but those cannot be quantified at this time.

IE Findings:

- a) *The development velocity remains in 'red' risk category.*
- b) *There is a cautious optimism that overall quality of design is improving.*
- c) *Solid time estimates are difficult to obtain.*

4 COMMENTS AND CONCLUSIONS

There is a cautious optimism that overall quality is improving.

While the plan still shows expected completion of the factory acceptance tests (FAT) by June 9th, 2020, there is little confidence that the target will be met. Progress velocity remains in risk category 'red'.

If those are available, addition of qualified resource with knowledge of coding and the HVDC/ electric utility industry is recommended.

Number of outstanding bugs that will be identified / remedied at later stages presents an unknown risk to Project schedule and S/W performance.

GE's project plan does not include full regression testing of the completed software release or provides time allowance for bug fixes between the project phases. That raises a question if that approach will ensure full functionality of this critical component.

NALCOR and Amplitude site representatives monitor and provide helpful feedback to both NALCOR and GE.