User Specifications for Operational and Switching Procedures, a Working Group Report

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***Abstract*—In general, power software lacks lockout/tagout (LOTO) procedures and transfer/switching procedures—both critical shortcomings. In 2008, this Working Group (WG) was created to develop methodology for software programs addressing operational procedures, switching procedures including LOTO, and transfer procedures. The "User Guideline Specification" provides this methodology. Software itself will be developed by software vendors. Related was a goal to present a clear, simple, mathematical, and graphical language to promote rigorous analysis and virtual verification of the applicable software; a unified suite for an operational, mathematical, and graphical language. Referenced papers provide a sound basis for work toward achieving this goal, a task which the WG commends to future authors and Working Groups. Although it is outside the defined scope, the WG notes that these basic concepts apply to other energy systems. The WG encourages interested parties to develop similar approaches for other energy systems.**

***Index Terms*—Lockout/tagout (LOTO), operating conditions, power system application software, safe work practices, switching procedures.**

I. Introduction

THE MANY software programs in use for power systems provide a powerful set of tools for analyses such as load flow, short circuit, voltage regulation, arc flash, and others. Typically, these programs share a common database with interacting programs. The troubling omission has been a program to address requirements encompassed by switching programs, particularly lockout/tagout (LOTO) programs for safety and transfer/switching procedures for system integrity and service continuity. Fundamentally, two obstacles inhibited development of switching software; one was lack of a comprehensive mathematical basis or set of algorithms by which such a program could be created, the second was absence of a practical way to incorporate mechanical and nonelectrical devices.

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The authors are members of the Operational Procedures for Power Systems' Transfer and LO/TO Functions Working Group of the Maintenance, Operations and Safety Subcommittee, Power Systems Engineering Committee, Industrial and Commercial Power Systems Department, IEEE Industry Applications Society.

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For more than a decade, a series of papers developing the theoretical foundation have been presented at IAS/ICPS meetings; a simple software program was presented to demonstrate the practicality of developing comprehensive programs; and this Working Group (WG) was created in 2008 to derive a way to provide the missing software. This WG report provides guideline specifications for obtaining the desired software.

Software as specified will be a tool to assist the User's Engineer in making decisions regarding operational procedures, including LOTO procedures for safety and switching/transfer procedures involving system integrity and service continuity. The Engineer is reminded that this software will complement other procedures, but will not eliminate the need for practices such as identifying (visually) and marking all cables and switches on a one-line diagram (to identify any sneak path of power), marking all temporary grounding cables on the one-line and labeling the cables, (to collect and visually verify that all grounding cables are removed before a switch is operated to power a system), and verifying system safety by visually checking before any switching is done.

The User is responsible for all decisions regarding application and use of this software; the User's Engineer is in the best position to know what is required.

This "User Guideline Specification" is a generic outline for editing by the User. Sections in *italics* are information for the User's Specifying Engineer, not part of the specifications for the Software Vendor. The intent is to help the User describe clearly and completely the software requirements for the User's application, or in essence, to focus on the User's needs rather than on a Vendor's preferences. It does not, however, require a Vendor to conform to a particular set of specific features and/or interfaces; Vendors can propose features provided by their own software product that best suit the specifications.

This report completes the assigned task.

II. User Guideline Specification for Operational and Switching Procedures

A. General

The purpose of this document is to obtain a software program that is fully integrated with User's existing software programs, such that it will assist the User in developing and documenting operational and switching procedures.

Include only applicable sections. Portions of these specifications offer choices in square [ ] brackets. Select an appropriate option in each case; delete options that are not essential. Edit the final document to eliminate any conflicts between sections and to ensure that it is complete, accurate, and understandable.

Validity of data provided in this specification is shown for the respective items.

Define the validity of each part of the data provided in the specification, such as drawings, equipment data, software programs, calculations, etc. Consider using data tabulation that includes a validity statement with each part of the tabulation. Consider using one of the following statements for each section:

[Information is accurate and complete as provided]; *or*

[Information is basically accurate and complete as provided but will require field verification in the following areas], *then list the areas; or Insert appropriate statement*.

B. References

The following publications form a part of this specification.

Select the applicable references.

1) IEEE Standards:
   - 1.1. P3007.1: Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems
   - 1.2. P3007.2: Recommended Practice for the Maintenance of Industrial and Commercial Power Systems
   - 1.3. P3007.3: Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems
2) NFPA 70E: Electrical Safety in the Workplace
3) European Standard EN50110 $(-1, -2)$: Operation of Electrical Installations, CENELEC
4) *Add other references as needed.*

C. Input Data

The following data are a part of these specifications, either by reference or by inclusion as appendices.

1) Drawings and calculations
   - 1.1. Normal and Switching one-line diagrams
     - 1.1.1. Drawing List: *List drawings by number and title in an Appendix or refer to a file*
     - 1.1.2. Source: *Specify where and how to obtain drawings if they are not included as part of the specifications*
     - 1.1.3. Validity: *Specify validity as described in the "General" section.*
   - 1.2. Calculations
     - 1.2.1. Programs: *Identify all existing related programs such as load flow, short circuit, arc flash, voltage regulation, stability, etc. Provide vendor's name and identify versions*.
     - 1.2.2. Source: *Specify how to obtain programs if they are not included as part of the specifications*
     - 1.2.3. Validity: *Specify validity as described in the "General" section.*
2) Equipment data and operating characteristics List under each item
   - 2.1. Sources of energy: *Identify by reference to drawings, tabulations, or other documentation*
     - 2.1.1. Utilities
     - 2.1.2. Local generation
     - 2.1.3. DC sources, batteries
     - 2.1.4. Retained excitation, e.g.,: capacitors, transformers, residual charges on cables
     - 2.1.5. UPS
     - 2.1.6. Emergency or temporary sources
     - 2.1.7. Nonelectrical stored energy sources, e.g.,: hydraulic accumulators, surge tanks, mechanical springs, gravity
     - 2.1.8. Validity: *Specify validity as described in the "General" section.*
   - 2.2. Loads: *Identify by reference to drawings, tabulations, or other documentation*
     - 2.2.1. Motors
     - 2.2.2. Lighting
     - 2.2.3. Communications
     - 2.2.4. *Other*
     - 2.2.5. Validity: *Specify validity as described in "General" section.*
   - 2.3. Switching equipment and protective devices *Identify by reference to drawings, tabulations, or other documentation*
     - 2.3.1. Switchgear
     - 2.3.2. Circuit breakers
     - 2.3.3. Transfer switches
     - 2.3.4. Motor Control Centers
     - 2.3.5. Protective devices
     - 2.3.6. *Other*
     - 2.3.7. Validity: *Specify validity as described in the "General" section.*
   - 2.4. Mechanical and nonelectrical devices that are considered a part of the system
     - 2.4.1. Key interlocks
     - 2.4.2. Grounding cables or connections
     - 2.4.3. *Other*
     - 2.4.4. Descriptions and locations are [shown on the one-line] *or* [tabulated in Appendix xx]
     - 2.4.5. Validity: *Specify validity as described in the "General" section.*
   - 2.5. Present Operational and Switching Information
     - 2.5.1. See Appendix yy. *Append present operational and switching procedures and sequences*
     - 2.5.2. Validity: *Specify validity as described in the "General" section.*
   - 2.6. Present LOTO Procedures and Sequences:
     - 2.6.1. See Appendix zz. *Append present LOTO procedures*
     - 2.6.2. Validity: *Specify validity as described in the "General" section.*
   - 2.7. Critical Loads:
     - 2.7.1. *Identify and prioritize critical loads, both for standard operating procedures and for special switching procedures*
     - 2.7.2. *Describe production and process constraints that impact system operation and switching*
     - 2.7.3. Validity: *Specify validity as described in the "General" section.*

NOTE: the following sections describe some, but not necessarily all, major required "deliverables."

D. Program Requirements

1) Scope of work:
   1.1. The Operations & Switching (O&S) program shall be capable of analyzing and developing procedures for the power system in its entirety as presented in the referenced documents. It shall also be capable of performing the same functions for selected portions of the system such as one bus or a group of busses.
   1.2. The procedures shall include detailed instructions for specific operational, switching, and LOTO procedures, including both de-energizing and restoring power circuits.
2) Changes:
   2.1. Retain the underlying programs and data without change so this information can be recalled readily as the permanent record.
   2.2. Provide means to enter data for the O&S program.
      2.2.1. Modified relay settings
      2.2.2. Mechanical and nonelectrical devices
      2.2.3. Modified transformer tap changes
      2.2.4. Modified operating limits or bounds
      2.2.5. Modified alarm settings
      2.2.6. Storage of the different one-line changes (i.e., scenarios)
      2.2.7. *Other data as appropriate. Show any additional special requirements here*.
      2.2.8. Provide means to modify circuit breaker settings on a temporary basis.
3) Existing programs:
   3.1. This O&S program shall be fully integrated with all existing programs.
   3.2. Existing programs shall run O&S data concurrently with the O&S program and shall store these outputs without changing or affecting any existing records or files.
4) Alarms, alerts:
   4.1. Show alarms for operating conditions that are out of established bounds.
   4.2. Show alarms that are out of bounds established for O&S procedures.
   4.3. Use highlights, flashing signals, color codes, or methods used in the underlying programs, and use these same methods for silencing or canceling alarms.
5) Documentation:
   5.1. Retain and identify internal records of all selected O&S procedures, including trial runs.
   5.2. Tabulate or capture by other means all alarms and alerts.
   5.3. Prevent automatic deletion of records.
6) Check lists:
   6.1. Provide a check list for switching functions suitable for keyboard entry.
   6.2. Provide a duplicate hard copy suitable for manual entry.

E. Output

1) Provide a sequence of operating or switching procedures:
   1.1. For switching from one condition or status to another
   1.2. For switching back to the previous status
   1.3. With means to check off each switching or operational step.
2) Present the effect of each step of the procedures as determined by the underlying programs, with clear indication of any questionable or out-of-bounds conditions.
3) Provide a method to display the O&S program output as each switching operation occurs.
4) Provide a record of switching events as they occur in sequence.
5) Preferred formats are.pdf and Microsoft Word.

F. Supplementary Support

1) Define the software training that will be required when the program is commissioned.
2) Define the recommended field support.
3) State how long the program will be valid and supported.
4) Define ownership of the program and documentation.

G. Terms and Conditions

Include User's "Terms and Conditions" as required.

APPENDIX

Note: The following papers are listed as additional, optional, reading for the Software Vendor. Essential items have been included in the specifications. Appendix is not a part of the specifications.

INDEX OF PAPERS ON ELECTRICAL SAFETY

[1] G. D. Gregory, J. H. Kusca, G. Parise, M. K. Sanders, and C. M.Wellman, "How do the NEC and IEC 60364 help provide electrical safety?" in *Conf. Rec. IEEE/IAS PCIC Conf.*, San Antonio, TX, 2000, pp. 323–331.

[2] G. D. Gregory, J. H. Kusca, G. Parise, M. K. Sanders, and C. M.Wellman, "How do the NEC and IEC 60364 help provide electrical safety?" in *Conf. Rec. IEEE IAS Annu. Meeting*, Rome, Italy, Oct. 8–12, 2000, pp. 2774–2781.

[3] G. Parise, G. Donato, G. Lucarelli, and C. Turella, "An electrical consulting board to improve safety in the electrical field," in *Conf. Rec. IEEE IAS I&CPS Tech. Conf.*, New Orleans, LA, May 12–19, 2001, pp. 31–35.

[4] G. Parise, S. Annibaldi, and L. Martirano, "Toward alignment of safety levels concerning electrical installations in EU," *IEEE Ind. Appl. Mag.*, vol. 7, no. 3, pp. 73–82, Jun. 2001.

[5] G. Parise, W. Moylan, and P. E. Sutherland, "Electrical safety for employee workplaces in Europe and in USA," *IEEE Trans. Ind. Appl.*, vol. 41, no. 4, pp. 1091–1098, Jul./Aug. 2005.

[6] K. G. Mastrullo, R. Jones, B. McClung, P. S. Hamer, and G. Parise, "Globalization of electrical codes and standards," in *Conf. Rec. IEEE IAS PCIC Conf., New Orleans*, LA, 2002, pp. 13–22.

[7] G. Parise and S. Pasqualini, "The electrical system "chessboard" as a useful tool for comparison between north American and European power systems," in *Conf. Rec. IEEE IAS I&CPS Tech. Conf.*, Clearwater, FL, May 3–5, 2004, pp. 5–10.

[8] G. Parise, R. E. Nabours, and L. B. McClung, "Relevance of competence in risk reduction for electrical safety," *IEEE Trans. Ind. Appl.*, vol. 44, no. 6, pp. 1892–1895, Nov./Dec. 2008.

Index of Papers on Operational Procedures

[1] G. Parise and E. Hesla, "Basic concepts and auto-check for clearing procedures," in *Conf. Rec. IEEE IAS I&CPS Tech. Conf.*, Sparks, NV, May 2–6, 1999, pp. 1–10.

[2] G. Parise and E. Hesla, "Electrical status space for clearing procedures in electrical installations," in *Proc. IEEE Safety Workshop*, New Delhi, India, Apr. 2000, pp. 55–60.

[3] G. Parise and E. Hesla, "Clearing procedures in electrical installations: The electrical status space," *IEEE Trans. Ind. Appl.*, vol. 38, no. 3, pp. 797–802, May/Jun. 2002.

[4] G. Parise and E. Hesla, "A new analytical language for clearing procedures in electrical installations," in *Conf. Rec. IEEE IAS Annu. Meeting*, Seattle, WA, Oct. 2004, pp. 1749–1754.

[5] G. Parise and E. Hesla, "A programmable language for clearing procedures," in *Conf. Rec. IEEE IAS I&CPS Tech. Conf.*, Saratoga Springs, NY, May 2005, pp. 147–153.

[6] G. Parise and E. Hesla, "The sources sets for operational procedures," in *Conf. Rec. IEEE IAS ICPS Tech. Conf.*, Dearborn, MI, May 2006, pp. 1–8.

[7] G. Parise, E. Hesla, and R. Rifaat, "Comprehensive design of electrical installations by integrating system configuration and operational safety aspects," in *Conf. Rec. IEEE IAS Annu. Meeting*, Tampa, FL, Oct. 2006, pp. 2631–2635.

[8] G. Parise and E. Hesla, "Transitions maps for integrity in operational procedures of electrical installations," in *Conf. Rec. IEEE IAS I&CPS Tech. Conf.*, Edmonton, AB, Canada, May 6–9, 2007, pp. 1–7.

[9] "Comprehensive design of electrical installations integrating system configuration and operational safety aspects," in *Conf. Rec. IEEE IAS I&CPS Tech. Conf.*, Edmonton, AB, Canada, May 6–11, 2007, pp. 1–10.

[10] G. Parise, E. Hesla, and R. Rifaat, "Architecture impact on integrity of electrical installations: Cut&tie rule, ring configuration, floating node," *IEEE Trans. Ind. Appl.*, vol. 45, no. 5, pp. 1903–1909, Sep./Oct. 2009.

[11] G. Parise, "Four color theorem explained by electrical operational procedures?" in *Proc. IEEE/I&CPS Tech. Conf.*, Clearwater Beach, FL, May 4–8, 2008, pp. 1–6.

[12] G. Parise, A. Gabelli, E. Berenato, D. Brambilla, and L. Signorelli, "Architecture of electrical installations: The node double two," in *Conf. Rec. IEEE IAS Annu. Meeting, Edmonton*, AB, Canada, Oct. 5–9, 2008, pp. 1–6.

[13] G. Parise, "Transitions theory for intersections/nodes and generalized euclidean kinematics in operation of electrical installations," in *Conf. Rec. IEEE IAS Annu. Meeting*, Houston, TX, Oct. 4–8, 2009, pp. 1–6.

[14] G. Parise, E. Hesla, and R. Rifaat, "Genetic code of electrical operational procedures: Lockout systems, simulators and training," *IEEE Trans. Ind. Appl.*, vol. 46, no. 2, pp. 569–574, Mar./Apr. 2010.

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After employment in industry, he moved into the fields of consulting practice and start-up firms.

Mr. Hesla has been active in AIEE and IEEE, including Chair of the "Yellow Book" (902-1998), Chair of a chapter of the "Red Book" (141-1983), past Member-at-Large of the IAS Executive Board, and past Chair of IAS Chapters Technical and Professional Outreach Committee. He received the RAB Larry K. Wilson Transnational Award in 1998 for innovative promotion of IEEE globalization. He is a Registered Professional Engineer in several States, has served as an expert witness, and holds three patents.