PPL EU REQUIREMENTS FOR TRANSMISSION CONNECTED FACILITIES TO BE OWNED AND OPERATED BY PPL EU

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Rev	Date	Sponsor	Reviewer	**SUBSTATION ENGINEERING INSTRUCTION** **PPL ELECTRIC UTILITIES CORPORATION**
1	7/14/17	NJM	GJ	
2	9/29/17	NJM	LEL	
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Record of All Issued Revisions

Revision	Page(s)	Section(s)	Description	Issue Date
0	All	All	Initial Issue	9/19/2014
1	All	All	Updated list of Attachments, removed expired web links, expanded list of equipment with approved vendors, added specifications that equipment must meet, updated 500kV yards to 4000A, updated circuit breaker requirements, updated 500kV CCVT ratio, added requirements for GIS, updated reference for Transmission requirements, updated fence requirements, updated line pull-off heights, general formatting and editorial updates	7/14/2017
2	7 5, 6, 7	1.1.1 5, 6, 7	Removed RTU requirement Updated language regarding perimeter fences to "Perimeter Security System".	9/29/17
3		1, 1.1, 1.1.3, and 10	Added clarifying information to specify minimum requirements for new IPP connections at 230 kV.	10/30/2018
4	5, 9, and 20	1, 1.1.3, and 10	Removed minimum requirements for 230kV switchyards specified in the introduction section, removed reference to drawings EU00507003_S001 and EU00507004_S001 in section 1.1.3 and specified that the typical layout arrangement in Section 10 is for breaker and a half design.	3/8/2019

Distribution:
1. RC 0880 – T&S Standards
2. RC 0883 – Substation Engineering
3. RC 0601 – T&S Asset Management
4. RC 0878 – T&S System Engineering

Table of Contents

1. Introduction

This document, with its six (6) attachments, includes the requirements for all facilities to be owned by PPL Electric Utilities (PPL EU); and describes the processes to validate that Interconnection Customers have met those requirements and have utilized acceptable vendors and systems. The PJM RTEP procedures and requirements shall also apply to all projects. PPL EU's standard 230 and 500 KV playbooks with associated references shall be used to govern the design.

When developers select the Option To Build in the PJM Generator Interconnection process, or are otherwise siting facilities for which PPL EU will take ownership, PPL EU has a legitimate and vested interest on behalf of itself and its customers in ensuring the proper siting of facilities. Proper siting affects customer satisfaction and environmental stewardship and ensures PPL EU and its customers are not exposed to unnecessary legal and operational costs in the short and long term. Refer to Attachment 7 for PPL EU's siting requirements.

1.1. Requirements

All projects shall meet the following requirements, in addition to this document and its references:

- 2-083 –Attachment 1: PPL EU Technical Requirements and its references.
- 2-084 – Attachment 2: Bulk Delivery Facilities and its references.
- 2-085 – Attachment 3: Relay and Control Facilities and its references.
- 2-086 – Attachment 4: Responsibilities Checklist.
- 2-087 – Attachment 5: AE Constructors Testing Companies.
- 2-088 – Attachment 6: Option to Build Major Equipment Approved Vendors.
- 2-098 – Attachment 7: Siting Requirements
- 2-081 – Transmission Substation Standards Manual: New Substation Development Playbook and 500-230kV AIS CB AND A HALF Reference Design
- National Electric Safety Code (NESC).
- All applicable ANSI, IEEE, NEMA, ASCE standards and NERC, Reliability First, and PJM guidelines.
- The information contained in this document, and its attachments, is intended as supplement to the standards listed above. It is not meant to supersede or conflict with any of these standards

or the applicable federal, state, and municipal standards, guides, laws, ordinances, rules, codes, and regulations.

- All construction drawings must be accepted by PPL EU before start of construction. PPL EU approval is only with regards to the general acceptability and does not relieve the developer of responsibility for correctness of design.

- All equipment bids shall be reviewed by PPL EU before placing orders for any equipment. Spare parts requirement and PPL EU training requirements may vary with different vendors.

1.1.1. Detailed review/concurrence process:

PPL EU will function as "Owners Engineer" in all aspects of the project. The developer is expected to cover the full cost of PPL EU's "Owners Engineer" function. Therefore, the cost of all PPL EU review/concurrence functions, including man-hours, expenses, and associated overheads will be paid by the developer.

The detailed review process in sub clauses below shall be followed. A sample check list of responsibilities is listed. (2-086)

PPL EU believes the following actions are a required minimum to ensure the proposed switchyard/substation meets PPL EU design, operational and maintenance requirements. Please refer to section 11 of this document for process flow documents and charts. These review activities, in no particular order, are:

- Kickoff meeting to define project, safety expectations and a high level review of design standards, approved contractors, milestones and schedule. All NERC Compliance Standards will apply with this installation.

- Establish expectations of a "Basis of Design" report that IPP will provide to PPLEU which provides a detailed summary of IPP work product.

- Drawing reviews (all disciplines, Civil-Structural, Physical-Electrical, and Protection and Control) with PPL EU approval of each level (*concept, preliminary design, for construction and as-built).* There may be multiple drawing approvals of the same drawings to ensure the construction drawings meet PPL EU's requirements.

- Review of detailed cut-over sequence and outage duration. This can impact initial design.

- Development and review of "Hold Points" where PPL EU's review and concurrence is required before proceeding with project work.

- Equipment bid reviews, design reviews, and approval drawing reviews, and pre-shipment factory inspections.
- Vendor and material approvals.
- Inspection of Site preparation, drainage, storm water retention, sedimentation control.
- Site grading inspection.
- Access road inspection.
- Review of test data (e.g. grounding tests, manufacturer's test data, commissioning test data).
- Selection of the proposed protection equipment, to insure operability with the existing remote terminals.
- Protective relay set point calculations for the IPP facility.
- Inspection of wetlands mitigation (if required).
- Review of NPDES permit.
- PUC filing for Transmission lines (PPL EU to file).
- PA threatened and endangered species review.
- Outage coordination of project with other PPL EU construction activities to support the IPP switchyard/substation installation.
- Periodic site visits and inspections of the IPP switchyard/substation during construction phase.
- Design coordination with various PPL EU systems for SCADA (includes TMS database), creation of SCADA PAS. Also, Alarm management System Digital Fault recorder, and PMU capability if needed.
- Review of civil engineering aspects such as core boring data, foundation designs, structure designs etc.).
- Review of and possible participation in factory acceptance testing of equipment (if required).
- Review and participation in commissioning tests, application of relay settings, SCADA testing, controls and interlocks testing.

In addition, because PPL EU will ultimately become the owner of this facility, all of thefollowing – except as noted – normally required studies, permits, and reviews must be completed by the developer with appropriate review by PPL EU:

- NPDES permit (estimated lead time 6 to 12 months)
- Phase 1 environmental review (required)
- Phase 2 environmental review (required if results of the phase 1 review dictate)
- Phase 1 Archeological Review, (PHMC) Phase 2 Archeological Review, (PHMC) (required if results of the phase 1 review dictate)
- Phase 3 Archeological review, (PHMC) (required if resultsof the phase 2 review dictate)
- PUC filing for line extensions to a new switchyard (estimated lead time 6 to9 months and PPL EU will make this filing)
- PA Threatened and Endanger Species Review
- Wetlands Encroachment Study Review
- DEP Approval of Erosion and Sedimentation Control Plan
- Local building code and Subdivision Requirements

1.1.2. General Technical Requirements

This document, PPL EU Technical Requirements for Transmission Facilities to be Owned and Operated by PPL EU Attachment 1, provides the general technical requirements for the integration of transmission connected facilities into the PPL EU system. However, Interconnection Customers should be aware that it may not cover all the details of such an interconnection, nor reference all theapplicable standards and requirements governing such an installation.

- The following Technical Requirements prepared by PJM Transmission Substation Design Subcommittee (TSDS), now the Transmission and Substation Subcommittee, (TSS) shall be utilized for the design of an interconnection facility. All of these documents can be found on the PJM website.

1.1.3. Conflicting Standards

Where the above standards or PPL EU documents conflict, written clarification shall be obtained from PPL EU in collaboration with PJM prior to completing the affected phase of the project.

Some of the guidance in 2-081 (Transmission Substation Standards Manual: New Substation Development Playbook and 500-230kV AIS CB AND A HALF Reference Design) does not apply to the minimum 230 kV and 500 kV designs described in 2-084 since 2-081 generally applies to 500-230 kV substation standards.

1.1.4. Safety

All work performed on PPL EU's transmission system and/or property shall be in accordance with applicable safety practices and OSHA requirements.

1.1.5. Validation Of Requirements

Consistent with the Section 8.3 of the PJM Open Access Transmission Tariff, inspection and testing of the completed facilities is required. After the construction is completed, PPL EU reserves the right to validate the operational readiness of the equipment and satisfactory operation of the design, as well as to repeat any test that it chooses. If there are substantive differences between the initial test and industry accepted norms or PPL EU test results, the tests with suspect results shall be repeated until satisfactory results are obtained.

1.1.6. Modifications Or Updates

PPL EU may modify and/or update these requirements to ensure compliance with system reliability standards.

1.2. Project Documentation

Project documentation shall include, but not be limited to:

- All design calculations
- Licensing and permitting documentation
- Bill of materials for major equipment, structures, and electrical bus work
- Manufacturers drawings, instruction books, and test reports for all Electrical equipment

- DC and AC schematic diagrams of all controls and relaying
- Wiring diagrams for all equipment, racks, assemblies and equipment interconnection, note: wiring or cable tabulation lists are unacceptable.
- All civil, structural, and electrical drawings required for construction.
- Drawing numbers shall be assigned by PPL EU. Drawing formats shall be per ANSI standards. Electronic versions shall be in AutoCAD format (contact PPL EU for preferred version). As built drawings shall be provided to PPL EU 90 days after completion of the pertinent phase of the project. I.e. an as graded drawing shall be provided within 90 days of completion of final grading. As built drawings are required for all phases of the project.

1.3. Major Substation Equipment

PPL EU will provide equipment purchase specifications as if PPL EU were purchasing the equipment. Spare parts to support maintenance and repair of the equipment for 10 years shall be provided. Maintenance Training on all unfamiliar equipment as defined by PPL EU shall be provided. (As an alternate, a prepaid 10 year maintenance, repair, and emergency response contract provided by the supplier could be considered.)

A current list of approved vendors for major equipment can be found in "2-088" Attachment 6.

Equipment included:

- Circuit Breakers 12kV and above
- Disconnect Switches 69kV and above
- Surge Arresters
- Power line Carrier wave traps
- PTs/CCVTs
- PVTs (Power Voltage Transformers)
- Power Transformers
- Emergency/Back-up generators
- Shunt Capacitor Banks

- Shunt and Series Reactors

- GIS/GIL

PPL EU will conduct reviews given 2 weeks advance notice of the review startdates. In no case shall the review be expected to be less than:

Bid reviews 10 business days
Approval drawings 20 business days
Factory inspections 10 business days
Witness production tests 10 business days

Developer must solicit bids from the PPL EU approved supplier list, using PPL EU equipment specifications. PPL EU must review and concur with the final awardee for all equipment bids. For Equipment with significant controls such as Circuit Breakers, Power Transformers, and switch motor operators, design new to PPL EU may require 2 or more iterations of approval drawings. This may have significant schedule impacts. PPL EU will participate in all design reviews and will have final say on all customer specific details. This includes normal approval drawings, factory inspections, and witnessing of production tests.

2. Protection and Control

A protection system is defined as those components used collectively to detect defective power system elements or conditions of an abnormal or dangerous nature, to initiate the appropriate control circuit action, and to isolate the appropriate system components.

In analyzing the relaying practices to meet the broad objectives set forth, consideration must be given to the type of equipment to be protected, e.g., generator, line, transformer, bus, etc., as well as the importance of the particular equipment to the integrity of the PPL Interconnection.

To accomplish the design objectives, six criteria for protection should be considered: fault clearing time, selectivity, sensitivity, reliability, dependability, and security.

The PJM Relay Subcommittee (Relay-sub) posted documents shall be followed in design of protection and control systems. These documents are posted on the PJM website.

PPL EU has recently updated its standard protective relaying requirements for Bulk Power Facilities. Specifically these requirements deal with:

- Approved relay vendors and models

- Approved routers and communication equipment
- Approved communications processors
- Approved substation computers
- The overall interconnection of all of the above equipment
- The required software and settings for all of the above equipment

Due to Cyber Security concerns, the programming as well as some aspects of the design will be by PPL EU. Please contact PPL EU to discuss further.

Facilities associated with generation in excess of 250 MVA will also need to have a Digital Fault Recorder installed. PPL EU will advise if this equipment will be programmed for PMU capability.

2.1. Transmission Substation Protection and Control Design

Description

PPL EU transmission substation protection and control design applies microprocessor relays that are capable of executing logic to perform required protection and control functions as determined by utility provided generic logic. All protection and control logic resides in the relays. Event records from the relays and communications processor are collected using DNP 3.0, level 2, protocol by a computer running alarm management software which provides local alarm annunciation. The events are also stored in an Oracle database that, communicates with a server making event reports available over the PPL EU internal network. The communications processor records events outside of relays and functions as the SCADA remote terminal unit. All control switches will be directly wired to the relays and a MIMIC bus will be provided for control and indication. PPL EU's R&C Design Intent EI-2-077 provides more details on the intent of the system operation.

2.2. Approved Major Hardware Items

Relays and Communications/Network Components:

- Contact PPL EU for the latest list of approved components.

Panels

- Shall meet PPL EU specification LA49000
- Shall be subject to PPL EU inspection and acceptance

2.3. Software

- Refer to Attachment 3

Note - This is not a complete list of hardware and software - it includes major items to convey the essence of PPL EU requirements. All requirements of document "2-085" must be met. Typical example drawings will be provided. If the example drawings are followed, PPL EU standard protection software will run correctly.

3. Equipment and Circuit Minimum Requirements

3.1. Ratings – Interrupting, Momentary, and Continuous

- All interconnecting station equipment shall have interrupting and Peak current ratings adequate for the currents detailed in the facilities study, but in no case shall these ratings, or the continuous current ratings be less than those in Table 1 below. The bus, connections, and ground grid shall withstand the symmetrical short circuit current for 2 seconds. Structure and equipment connections to the ground grid shall withstand the symmetrical short circuit current for 0.5 second. Bus work, connections and connected equipment, ground grid and connections, and portable grounds, shall withstand the peak current (as defined in IEEE C37.04 and IEEE C37.100 with a duration of 0.167 second) and all forces and movement associated with the peak current, without damage or reduction in minimum electrical clearances (below "temporary closeness").

3.2. Table 1: Minimum Short Circuit (Interrupting), Peak, and Continuous current Ratings*

System Voltage (kV)	Symmetrical short circuit rating (kA)	Peak current rating (kA)	Continuous
500	40	110	4000
230	50	130	2000
138	40	104	2000

*Table is of minimum values, higher ratings may be required.

Emergency ratings are covered in Clause III of Attachment 2 "Bulk Power Delivery Facilities".

3.3. Standard Spacing, Minimum Clearances and Insulation Coordination (BIL)

- Standard spacing, clearances and required BIL levels refer to Attachment 1.

3.4. Circuit Breakers

- Circuit Breakers shall comply with PPL EU specification A245251 or A242501.
- All equipment shall be new. Used equipment is not acceptable.
- Dead Tank Style SF6 single pressure circuit breakers shall be used with composite bushings. The ambient temperature range shall be -40C to + 40C. Besides the lower limit on ambient temperature, the breakers shall be in accordance with IEEE C37.04 and C37.04a, and tested in accordance with IEEE C37.09 and C37.09a. A first pole to clear factor of 1.5 shall apply. The interrupting rating of the circuit breaker shall meet or exceed the duty as specified in Table 1 above. Rated interrupting time shall be 2.0 cycles (33ms). All circuit breakers shall have short line fault capability at their short circuit rating. If TRV delay capacitors are required to achieve this rating they shall be located on the line side of the breaker disconnect switch. The capacitance current switching class shall at a minimum be Class C1.
- A minimum of two (2) ANSI C800/0.3B1.8 metering class multi ratio (5 lead) bushing current transformers, with 5 Amp secondary, are required on each bushing. The current rating shall be appropriate to the rating of the circuit breaker, and coordinated with the relay protection scheme. A thermal rating factor of 2.0 shall be used for all current transformers. More than two current transformers may be required in certain cases.
- All CT leads shall be terminated on GE Type EB-27 6-pole shorting terminal blocks, one for each CT. All secondary CT wiring shall be a minimum of #12 AWG.
- Control circuits shall operate on 125V DC both trip and close.
- Two mechanically and electrically independent trip coils shall be provided.
- All terminal blocks shall be States Type NT. All control wires to be minimum #14 AWG and to use ring tongue compression terminals. All customer terminations are to be on terminal blocks.
- Wiring space 6” from side walls and adjacent equipment and 10” from the bottom of the housing to be provided around all terminal blocks.
- Anti-pump scheme required X – Y relay scheme is preferred.

- Local push buttons are required for local breaker operation. One for close and one for trip.

- Automatic trip and block closing functions:
  - Low mechanism energy (lock out level) usually trip and block closing
  - Low SF6 (lock out level) automatic trip and block closing

- Breaker Alarms:
  - Low mechanism energy
  - Low SF6
  - Other alarms as required by CB manufacturer.

- Condensation mitigation heaters in cabinet shall be 250V AC rated.

- A 20A 120V duplex receptacle shall be provided. A 100W switched light for each separate cabinet or panel, and 1- 50A 3phase 4 wire 240V receptacle shall be provided.

3.5. Disconnect Switches

- Disconnect switches shall comply with PPL EU specification LA25000.

- Disconnect switches shall be 3 insulator vertical break, gang operated. Reverse loop contacts shall be used. Arcing horns shall be provided. Parallel inter-phase operating pipes and hand crank operators or motor operators shall be provided. All switches shall have full ice break capability with ¾" radial ice on all components. Pipe mounted auxiliary switches shall be provided as required by the control scheme.

- Disconnect switches 138 kV and above shall be motor operated. Disconnect switches for 69kV shall have provisions for a motor operator.

- All 500 kV disconnect switches shall have integral hand cranked ground switches

- All switches with motor operators shall have 125V DC controls and motors. All customer connections shall be through States NT sliding link terminals blocks.

3.6. CCVTs

- CCVTs shall comply with PPL EU specification A151579.

- 200VA metering accuracy 3 winding with 2 200VA 0.3Z windings and one 50VA 1.2 Relay winding.

- 230kV 1050kV BIL ratio 1155/2000:1:1:1 with nominal 115V/67V secondary
- 500kv 1800kV BIL ratio 2500/4350:1:1:1 with nominal 115V/67V secondary, with carrier accessories.

3.7. Wave Traps

- 0.265 mH with adjustable wide band tuning to accommodate the carrier channel frequency being used.
- Continuous current rating shall be 25% higher than the circuit to which it is installed [example: if the circuit is 2000A, a 2500A trap shall be used.]

3.8. Surge Arresters

- Surge arresters shall comply with PPL EU specification A151581.
- Surge arresters shall be ANSI/IEEE Station Class MOV type, gapless, polymer housed, rated with the duty cycle and MCOV ratings per the referenced specification above.

3.9. Current Transformers, column type

- A power factor test tap shall be provided. The continuous current and emergency current ratings must equal or exceed the circuit ratings to which it is connected. 5 Amp, 5 lead (multi ratio) ANSI standard secondary's shall be provided. CT cores and secondary's shall have a thermal rating factor of 2.0. All cores shall be C800/0.3B1.8 metering class minimum.

3.10. GIS/GIL

- GIS shall conform to PPL EU specifications EU00507317, EU00515971, and EU00515264.
- GIS shall be installed inside a pre-engineered metal building
- GIS and GIL shall have online gas density monitoring systems and permanent camera systems.

4. Transmission Line Standards

Transmission line facilities shall be designed and built per PPLEU's most current Transmission Engineering Instructions, Transmission Construction Standards and TransmissionSpecifications. For design criteria this shall include TEI's 8-000-001 and 8-000-002. Additionally, designs shall follow PPL EU's Transmission Design Philosophy Document.

5. Grounding

- Ground grids shall be designed in accordance with PPL EU specificationsA203863 and A200157.
- All switching and substation grounding grids shall be constructed to meet the requirements of IEEE 80, the IEEE Guide for Safety in AC Substation Grounding. A grounding grid study which demonstrates the requirements of IEEE 80 is required, and the resistance to remote earth, of the completed ground grid, shall be tested. A value of 1 ohm or less is expected.
- All switching and substation grounding grids shall be constructed with 4/0 AWG, or larger, copper, and shall be installed a minimum of 24 inches below grade.
- All pigtail connections to equipment and structures shall be made per PPL EU specifications, and all equipment and structures shall be connected by at least two connections to the ground grid. All equipment and structure grounding connectors shall meet the requirements of IEEE 837-2002, IEEE Standard for Qualifying Permanent Connections for use in Substation Grounding.
- All below grade connections shall be (exothermically welded or mechanical connectors suitable for direct burial) per PPL EU specifications.
- All metallic fences, platforms, and railings within a station shall be grounded by cable connections and not rely on mechanical contact with supporting structures. All discontinuous pieces shall have two connections to the ground grid.
- The perimeter security system shall be grounded a minimum of once every 100' of length with a minimum of one ground on each section. As a part of the ground grid, a ground ring 3' outside the perimeter security system shall be installed around the periphery of the substation including the extended area for any gates swing shall also be included in the ground grid.

5.1. Temporary Safety Ground Points

Safety ground points shall be installed to accommodate a 4/0 Cu or larger portable safety ground:
On both sides of each disconnect switchand on circuit breakers where applicable.

5.2. Ground Grid Testing

Testing of the ground grid shall be performed using the fall of potential method before the ground grid is connected to any neutrals, counterpoise, overhead ground wires, or any other ground conductors. The apparent resistance to remote earth shall be recorded. Additionally a continuity test shall be done on each "pigtail" intended to connect structures, equipment, ground mats, etc., to the groundgrid. These tests must be reviewed by PPL EU. If remediation is necessary to lower grounding resistance, the testing shall be repeated. [If tests are performed when the ground is frozen, probes must be driven at least 1' below the existing frost line.]

5.3. Ground Mats For Disconnect Switch Operators

A ground mat (Galvanized Subway Grating) shall be furnished under each disconnect switch such that the operator can stand on the mat and operate the switch manually without stepping off the mat.

6. Station Perimeter Security System Requirements

All substation perimeter security systems shall meet or exceed the requirements of National Electric Safety Code C2, IEEE Std. 80, IEEE Std. 1119, and NERC. The local municipality shall also be contacted to determine applicable, if any, requirements of the local municipality. There are several levels of perimeter security systems, ranging from expanded metal panels to concrete walls. The level of perimeter security will vary based upon the criticality and vulnerability of the substation and the FERC/NERC guidelines. Therefore, PPL EU shall advise the level of perimeter security, and in all cases, shall provide the appropriate specification for a specific site.

7. Yard Requirements

- All yards shall be surfaced in accordance with PPL EU specification A197973.
- All switching and substation yard areas shall be covered with of 6" of AASHTO #57, clean crushed stone or approved equal. The crushed stone surface shall extend a minimum of 10' beyond the substation perimeter security system.
- In addition to specific equipment or task lighting, the overall yard area shall be illuminated as required in the National Electric Safety Code. Overall lighting shall meet local municipality requirements.

- Drainage: Sufficient subsurface drainage shall be installed to keep the yard surface dry and free of standing water.

- SPCC provision shall be made to retain any equipment oil spill within the Substation. An SPCC plan must be developed.

8. Foundations

- Concrete foundations shall comply with PPL EU specifications A190974 and A190975.

- Foundations shall be designed for the loading requirements of the structure/ equipment they are supporting. A minimum 3" cover is required around all reinforcing. Minimum foundation depth from finished grade is 4'.

- Foundation projection above the crushed stone finished grade shall be 6" plus or minus 3".

9. Control Equipment Shelter

- A control equipment shelter shall be provided to house all protection and control equipment.

- The control equipment shelter shall comply with PPL EU specification A204524 (pre-engineered metal building) or EU00518273 (pre-fabricated metal building).

- Two (2) entrances shall be provided one at either end on the short walls. One shall be a single 36" x 84" door and the other shall be a double door with a 72" wide opening 96" high. (Use of a removable transom may be acceptable)

- Station batteries shall be installed on a concrete pad with an acid retaining dike around them sufficient to contain acid from all battery cells therein.

- An electrically protected phone circuits may be required.

- HVAC equipment shall be provided for the control cubicle to keep internal temperature between 15 C and 25C, in the climate where cubicle will be constructed. For cooling assume in internal heat generation of 10kW. Humidity must also be controlled to be below 60%RH.

10. Substation Layout and Design Criteria

The typical layout shall be arranged to accommodate PPL EU standards. Requirements for future expansion will be detailed in the facilities study. A typical breaker and a half bay arrangement shall be:

- Bus
- Disconnect switch
- Line breaker
- Disconnect switch
- Line terminal with CCVTs, line entrance arresters (500kV required and provisions for future on the 230kV system), TRV delay capacitors (if needed)
- Disconnect switch
- Tie breaker
- Disconnect switch
- Line terminal with CCVTs, line entrance arresters (500kV required and provisions for future on the 230kV system), TRV Delay capacitors (if needed)
- Disconnect switch
- Line Breaker
- Disconnect switch
- Bus

Note that a double breaker double bus arrangement will follow a similar layout as above, but eliminates the tie breaker, the two tie breaker disconnect switches, and one line terminal with its associated equipment.

The bay where a generator lead line is terminated is typically a double bus, double breaker arrangement with sufficient spacing to allow for a third breaker (and associated equipment) for future breaker anda half design.

Busses and connections shall be high enough to allow vehicle access throughout the switchyard. The exception could be leads to circuit breaker bushings and PVTspending layout. If the low connections are horizontally within phase to ground clearance of a substation roadway, a physical barrier must be provided to restrict tall vehicles from the affected area.

PPL EU general practice is to mount disconnect switches on 15' high structures such that at the disconnect switch terminal pad the roadway clearance in the NESC standards can be obtained.

10.1. Wind, Ice, and Short Circuit Loading

All conductors and equipment and structures must withstand mechanical loads and agree with PPL EU's latest design criteria:

- Loads developed during the peak short circuit current per Table 1 (or facilities study whichever is greater).
- Simultaneous extreme wind 100MPH with a 25% gust factor 25#/square foot projected area for cylindrical members, 32#/square ft. projected area for non-cylindrical members
- 1" radial ice loads with 30 MPH coincident wind.

10.2. Bus and Connections

230KV Bus

- Bus must be designed in accordance with IEEE 605.
- Typical bus is a strain bus design with 2 conductor per phase 1590kcmil ACSR.
- Strain bus structures conductor max design tension is 13,500# per wire (2 conductors per phase12" apart) wind and ice values per TSS technical requirements; attachment height will vary with voltage.
- To be rated for 50 kA fault duty, unless otherwise stated.

500KV Bus

- Bus must be designed in accordance with IEEE 605.
- Typical bus is a rigid bus design with 5" aluminum tube including a damping wire.
- To be rated for 40 KA fault duty, unless otherwise stated.

Conductor ampacity shall be determined following the PJM TSDS Rating guide for substation bus conductors. In addition to the temperature limits in the guide, it must be assured that the temperature limits for any connected equipment or insulated cables is not exceeded at the connection point, during emergency overloads. Multiple conductors per phase may be required to achieve continuouscurrent ratings.

Preferred conductor sizes:

- 795kcmil ACSR 34/19
- 1590 kcmil ACSR (45/7)
- 2493 kcmil ACAR
- 4" schedule 80, 6063 –T6 Aluminum Tube
- 5" schedule 80, 6063- T6 Aluminum Tube

Flying taps are used to connect cross circuits at a lower elevation in the 230Kv design. A-frames made of aluminum tube are used to connect cross circuits at a lower elevation in the 500 KV design.

Access roads must be provided to each disconnect switch operator and each circuit breaker. Circuit breakers are to be installed such that removal of the contact mechanism is toward the road. A Maintenance platform must be supplied with each 230kV circuit breaker.

Where rigid bus is used to connect to circuit breakers, appropriately rated LAPP "Doble test" isolating links shall be installed above the circuit breaker. All 500KV circuit breakers must utilize a LAPP "Doble test" isolating link on the circuit breaker bushings. Ridged bus will require expansion connectors to allow for bus expansion and contraction over the operating temperature range -40C to +125C

10.3. Station Post insulators

230kV post insulators shall be 900kV BIL Porcelain, high strength 80" long with 4 - 5/8" tapped holes on a 5" b.c. ANSI T. R. 308.

Requirements for 500KV insulators can be found in PPLEU's Transmission Substation Standards Manual for 230-500KV

10.4. Substation Structures

All substation structures shall be designed and fabricated in accordance with the ASCE "Guide for Design of Substation Structures". All Steel Structures shall have a galvanized finish in accordance with ASTM A123.

10.5. Line Dead End Structure (Back Bone)

230KV

- Frame type 54' wide bend to bend centers.
- Line pull-off height 61'
- Line pull of phase spacing 18'
- Line pull off tension 10,000#/wire
- Line pull off angle up to 15 degrees either side of center, vertical and horizontal.
- Down-comer spacing 15'
- Down-comer to support suspension mounted wave trap up to 3150A size with up to one trap per phase (i.e. 3 wave traps)
- Overhead shield wire termination on top of the A frame bent 81' high
- Shield wire max tension 5000#
- Shield wire pull-off angle up to 15 degrees either side.
- Each "A" frame to support shield wire terminated on one or both sides.

500KV

- Frame type 90' wide bend to bend centers.
- Line pull-off height 80'
- Line pull-off phase spacing 30'

- Line pull-off tension 35,000#/wire
- Line pull-off angle up to 15 degrees either side of center, vertical ah horizontal.
- Down-comer spacing 25'
- Down-comer to support suspension mounted wave trap up to 3150A size with up to one trap per phase (i.e. 3 wave traps)
- Overhead shield wire termination on top of the "A frame bent 25' high"
- Shield wire max tension 10,000#
- Shield wire pull-off angle up to 15 degrees either side.
- Each "A" frame to support shield wire terminated on one or both sides.

Line Dead-End Structure Design criteria to be confirmed with PPLEU before engineering is started.

10.6. Control Cables

All control cables and power cables shall be electrically and magnetically shielded. Shield shall be a full coverage minimum 3 mil copper tape, solidly grounded at both ends. General purpose control cables shall be stranded #10 AWG conductors with 30 mils (600V) of flame retardant polyolefin insulation. Smaller conductor may be acceptable for some very low signal applications. All multi conductor cables shall be jacketed with a flame retardant jacket as CSPE oil and chemical resistant, suitable for direct sun exposure, and operation totally submersed in water.
Color code ICEA E2 is preferred.
PPL EU standard sizes: 2 conductor, 4 conductor, 7 conductor, 12 conductor.

10.7. Control Cable Raceways

- Main runs for control cables shall be in preformed, H-20 rated concrete cable trenches (Synertech Cable Trench System).
- Cable runs from the concrete cable way must be in 2" minimum schedule 40 PVC or ABS electrical grade outdoor rated conduit. Maximum single conduit size is 4". Conduit sweeps above ground shall be GRC if exposed to vehicle traffic.
- All cable raceways shall have sufficient subsurface drainage installed to keep the raceway dry.

10.8. AC Station Service

- A minimum of 2 independent sources of station service with automatic throw-over are required. PPL EU preferred transfer switch is ONAN with integral bypass switch.
- Voltage shall be 120/240V 3 phase 240V delta with one leg center tapped and grounded. 300kVA capacity is suitable in most applications without power transformers.
- At least one source must be derived from the bulk power system. When no power transformers are available, Power Voltage Transformers shall be used. The second source may be from a utility 3 phase distribution line. In some cases an emergency engine generatoror provisions for one may be required. In such cases a suitable load bank will be required for periodic load testing of the engine generator. Contact PPL EU for engine generator requirements.

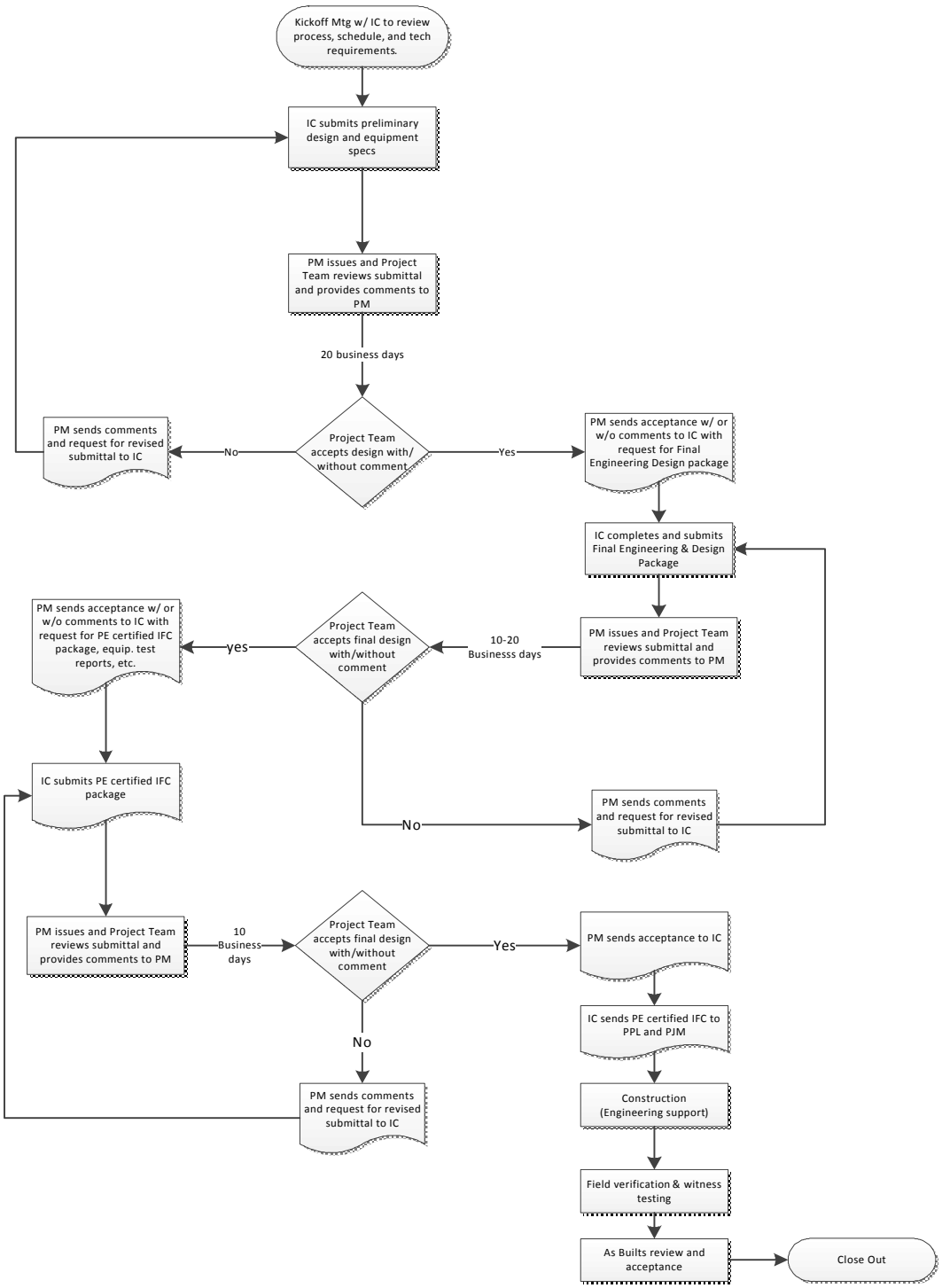
10.9. DC Station Service

- Primary and backup 125V batteries shall be provided to supply control system load.
- Batteries shall be sized to carry all control system load for a minimum of 24 hours and have ability to operate all circuit breakers and motor operated switches simultaneously, at the end of the 24 hour period.
- The batteries shall each be 60 Cell flooded lead acid type.
- Batteries should be in an arrangement no higher than 2 steps with a mid-point circuit breaker having an auxiliary contact.
- Two (2) independent battery chargers shall be provided per battery.
- Primary and backup DC panel boards are required. The DC panels shall be of the fused switch type, negative leg with slug. Provisions must be provided to connect an emergency “portable” battery to each panel.

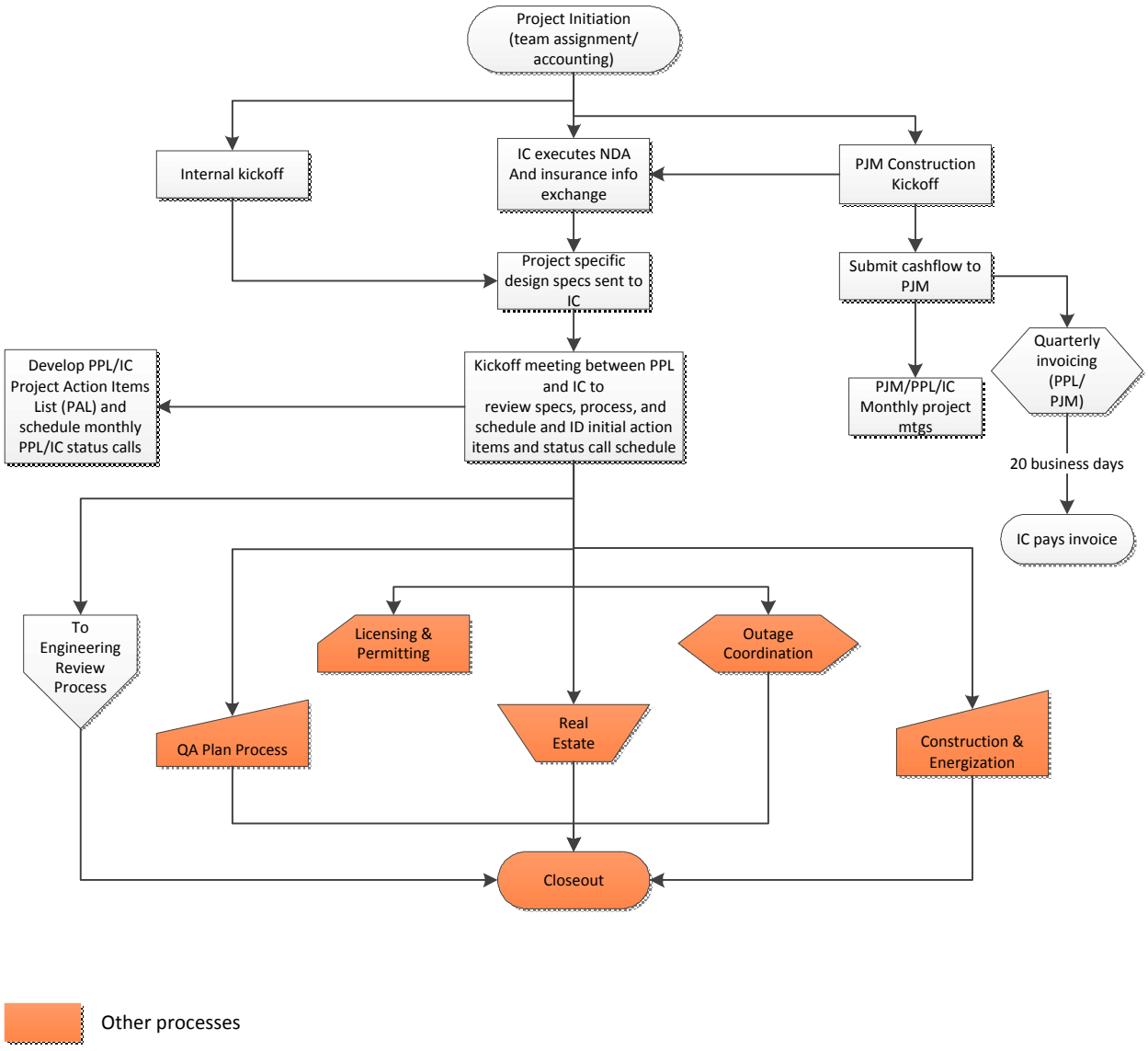
11. Process Procedure

11.1. Customer Interconnection Upgrade

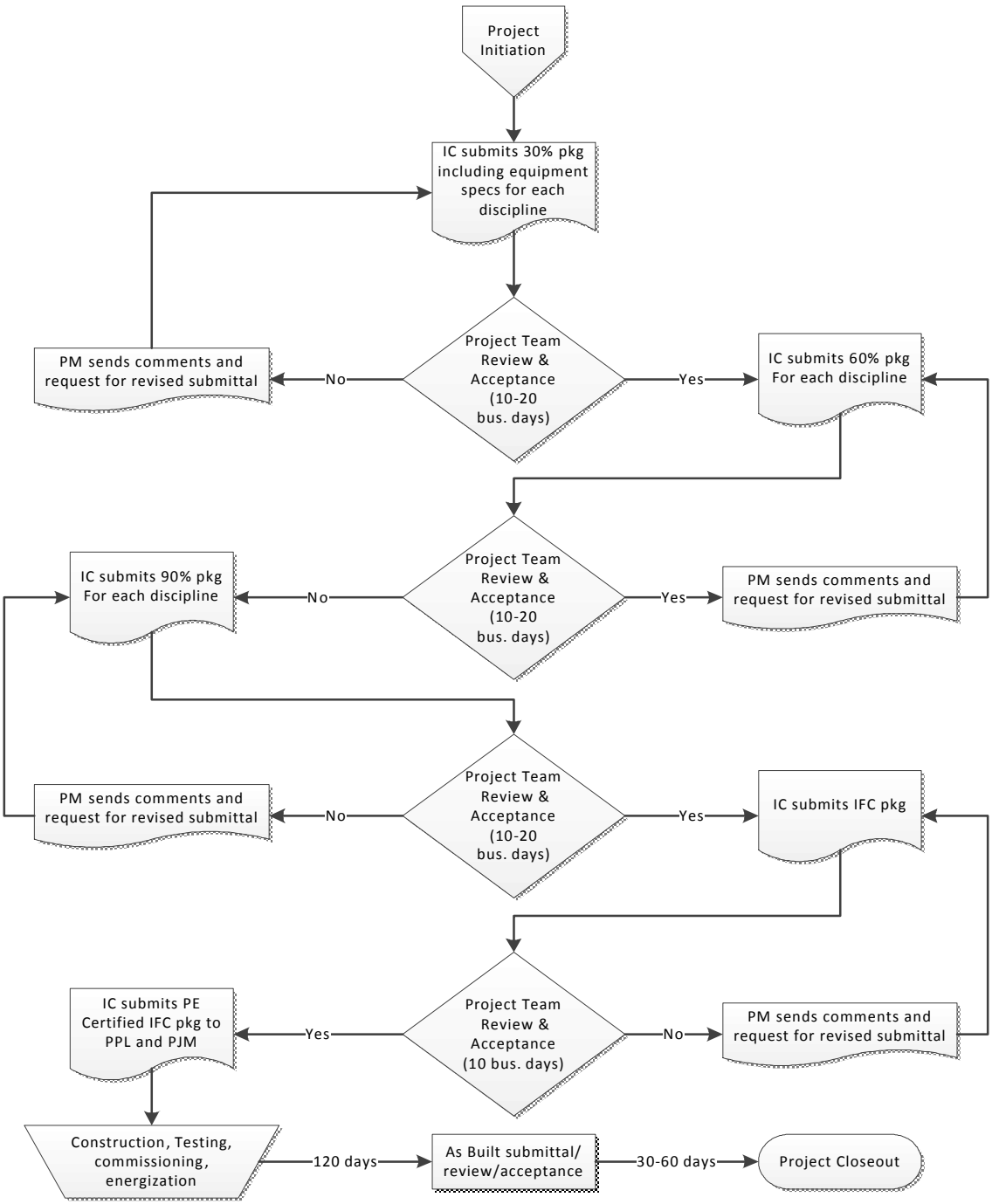
Interconnection Customer Attachment Facilities Engineering Review and Acceptance



LOCAL UPGRADES BY INTERCONNECTION CUSTOMER
Project Initiation



LOCAL UPGRADES BY INTERCONNECTION CUSTOMER
Engineering Review



11.2. FERC Generator Interconnections

FIGURE 1
FERC JURISDICTIONAL GENERATOR INTERCONNECTIONS STAGES