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SOW: Technical Specification for the EBIS 100.625 MHz RF System Power Amplifier			**Revision:** 01

TECHNICAL SPECIFICATION
for the
EBIS 100.625 MHz RF System Power Amplifier

Quality Classification: A-3

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Revision #	Effective Date	Summary of Change
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01	July 1, 2026	Technical clarifications, editorial corrections

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LIST OF ACRONYMS

AC	Alternating Current
BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates
CW	Continuous Wave
DC	Direct Current
DHCP	Dynamic Host Configuration Protocol
EIC	Electron-Ion Collider
EMC	Electromagnetic Compatibility
EPICS	Experimental Physics and Industrial Control System
ESH	Environment, Safety and Health
ESR	Electron Storage Ring
FET	Field-effect transistor
FPC	Fundamental Power Coupler
GaN	Gallium Nitride
GND	Ground
GUI	Graphical User Interface
HMI	Human-Machine Interface
HPRF	High-Power RF
LDMOS	Laterally Diffused Metal Oxide Semiconductor
LED	Light-Emitting Diode
MTBF	Mean Time Between Failures
NTP	Network Time Protocol
PLC	Programmable Logic Controller
RF	Radiofrequency
RF-PA	Radiofrequency Power Amplifier
SRF	Superconducting Radiofrequency
SSPA	Solid-State Power Amplifier
VAC	Volts Alternating Current
VSWR	Voltage Standing Wave Ratio

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Technical Specification for the EBIS 100.625 MHz RF System Power Amplifier

1 SCOPE

This document defines the technical specifications for the Electron Beam Ion Source (EBIS) 100.625 MHz Radiofrequency (RF) System Power Amplifier to be used at the Electron Beam Ion Source (EBIS) at Brookhaven National Laboratory (BNL) managed by Brookhaven Science Associates (BSA).

1.1 Background

The Electron Beam Ion Source, EBIS, is a Preinjector for a new Nuclear Physics Facility, the Electron Ion Collider and the NASA Space Radiation laboratory. The EBIS consists of an ion source designed to deliver milliamps of current of any ion species and charge state from protons to uranium. It is followed by the Radio Frequency Quadrupole, RFQ, accelerator and a Linear Accelerator with a final energy output of 2 MeV/u. This Specification will address the Power Amplifier for these accelerating cavities.

1.2 Definitions

Local Protection – Protection designed to be applied at the Solid-State Power Amplifier level.

Solid-State Power Amplifier (SSPA) – The Solid-State Power Amplifier (SSPA) comprises all subsystems (AC distribution, DC power supplies, RF, cooling, control) assembled in a functional device that provides RF power amplification. This term is mutually exchangeable with EBIS 100.625 MHz RF System Power Amplifier for this document.

Amplifying Stage – An Amplifying Stage is defined as the group of identical RF amplifiers that are operated in parallel to provide signal amplification within the SSPA. A SSPA usually has at least a couple amplifying stages.

RF Device – An RF Device is an RF power field-effect transistor (FET). It usually has one or two sets of gates and drain terminals, a metallic flange that is also its source terminal, and either a plastic or ceramic package covering its semiconductor elements.

Radiofrequency Power Amplifier (RF-PA) – A Radiofrequency Power Amplifier (RF-PA) is defined as the modular unit of the last Amplifying Stage within the SSPA. It may have one to several identical RF Devices operating in parallel with embedded RF splitting and combining structures. A SSPA may have up to several hundred RF-PAs.

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Remote Control – The Remote Control system is BSA's control system to handle communication between different equipment. It will be implemented via Experimental Physics and Industrial Control System (EPICS).

Soft Limit – An adjustable limit to a fault or warning condition which may be further sensitized by the end user.

Hard Limit – A limit to a fault or warning condition that is locked behind contractor-protected password, meant for critical SSPA protection.

2 APPLICABLE DOCUMENTS

The following specifications, standards and drawings form a part of this specification to the extent specified herein. Unless otherwise specified, the applicable revision level of these documents shall be that in effect on the date of the solicitation or contract. Exceptions must be approved in writing by BSA.

In the event of a conflict between the applicable documents and this specification, the Contractor shall immediately notify the BSA Contractual Representative who shall in each instance determine which document takes precedence and advise the Contractor accordingly. Failure to notify BSA of a document conflict shall not relieve the Contractor's responsibility to ensure full compliance with all requirements.

Document Number	Document Title
1610007SOW	Statement of Work for the EBIS 100.625 MHz RF System Power Amplifier
IEC 61000-6-2	Immunity Testing of Industrial Equipment
IEC 61000-6-4	Emission Standard for Industrial Environments
29 CFR 1910 Subpart S	Occupational Safety and Health Standards 1910 Subpart S – Electrical
NFPA 70E-2021	Standard for Electrical Safety in the Workplace Articles 340, 350, 360
UL 508	Standard for Industrial Control Equipment

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3 SPECIFICATIONS

3.1 SSPA Characteristics

The SSPA be constructed with solid-state devices. Its mode of operation shall be Pulsed. Isolated RF combiners are preferred but not required.

Regardless of the RF output power specification, the SSPA shall fulfill the following specifications. The SSPA interface specifications are shown in Table 1. The environmental specifications are shown in Table 2. The specifications of Pulsed operation are shown in Table 3 and Table 4.

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Table 1: SSPA Interface Specifications

Parameter	Min.	Nominal	Max.	Unit
Reference impedance (input and output)		50		ohms
Input RF connection		Type N (F)		N/A
Gating Connection		Type BNC (F)		N/A
Output RF connection[1]		4-1/16" EIA		N/A
3-Phase AC voltage input	187.2	208	228.8	VAC
Single Phase AC voltage input (for controls)	108	120	132	VAC
AC frequency		60		Hz
Power Factor	0.92			N/A
3-Phase 208 VAC connection		Through holes in a bus bar inside the AC power rack.		N/A
Single Phase 120 VAC connection		1 IEC 3-pin inlet to the control rack		N/A
Remote control connection		RJ-45		N/A
Cooling system		Tap water		N/A
Coolant tube material		Copper or stainless steel		N/A

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[1] RF power must exit the SSPA from the top.

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Table 2: SSPA Environment Specifications

Parameter	Min.	Nominal	Max.	Unit
Lifting		At least 3 mounting holes prepared for crane lifting with crane eye bolts and/or standard notches for forklift		N/A
Audible noise at 1 m distance			70	dB(A)
Tolerable coolant input temperature	30	35	40	ºC
Tolerable ambient temperature	15		40	ºC
Tolerable relative air humidity			65%	N/A
Tolerable coolant input pressure		80-100	150	psi
Tolerable barometric pressure	29.50			inHg

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Table 3: SSPA Specifications

Parameter	Min.	Nominal	Max.	Unit
Operating frequency	100.125	100.625	101.125	MHz
Gain (over 40 dB dynamic range)[2]	83.94	85.44	86.94	dB
Phase linearity (over 40 dB dynamic range)			25	º
Steady-state forward power	350			kW
Noise figure			10	dB
Input return loss at nominal frequency	20			dB
Input return loss across operating frequency	20			dB
Relative power of harmonic tones			-30	dBc
Relative power of spurious tones			-80	dBc
RF signals sampling power at nominal power (Section 3.4)		10		dBm
Group delay			200	ns
AC to RF efficiency	55			%

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[2] At no point shall the gain deviate more than 1.5 dB from nominal. The transfer curve of output power versus drive power shall be a smooth curve devoid of discontinuities or abrupt changes. 40 dB dynamic range specifies from nominal output power.

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Minimal RF on/off ratio[3]	85.44			dB
Blanking Speed			1.5	µs

Table 4: SSPA Pulsed Specifications

Parameter	Min.	Nominal	Max.	Unit
RF pulse width	0.01	1.0	1.2	ms
RF duty cycle	0.1	1.0	1.2	%
Rise time			1	µs
Fall time			1	µs
Pulse droop (at maximum pulse width)			0.2	dB
Pulse overshoot		0.1	0.2	dB
Pulse ringing (not including pulse overshoot)		+/- 0.05	+/- 0.1	dB
Settling time of pulse ringing		50	100	ns
Phase Error Over Pulse (at maximum pulse width)		1.0	2.5	º

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[3] Gain difference measured between DC ON and RF ON machine states.

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Table 5 presents specifications of gain, phase and group delay deviations across all units from any amplifying stage across all SSPAs.

Table 5: Unit-to-unit RF Specifications across all SSPAs

Parameter	Min.	Nominal	Max.	Unit
Gain deviation at operating frequency			0.25	dB
Phase deviation at operating frequency			7.5	°
Group delay deviation at operating frequency			5	ns

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3.1.1 Stability

The RF SSPA shall be unconditionally stable over the entire load space and dynamic range.

3.1.2 Forward Power Degradation versus Load VSWR

Up to 3:1 Load VSWR, the SSPA shall output 100% of its nominal power. For higher values, the SSPA must present a fault and a transition from the RF ON machine state. The SSPA shall not be damaged in the event of a short or open circuit on the RF output.

3.1.3 Input Overdrive Protection

There shall be hardware within the RF SSPA for input overdrive protection. The hardware shall limit the RF power at the input of the system, and the RF SSPA shall not be inhibited.

3.1.4 Burn-in Testing

The SSPA shall go through a 48-hour Burn-in Test at full rated power at the Contractor's site, without any faults, warnings, trips, or failures.

3.1.5 Redundant Operation

The SSPA must be able to provide 300 kW output power with up to 10% of all RF-PAs either in a failed or inhibited state. If a RF-PA fails or is inhibited during operation at any power level, the SSPA must be able to withstand a sudden change in input power that will try to compensate for the failed/inhibited RF-PA power loss in order to restore the rf output power to its previous level before the failure or inhibit.

The SSPA must be able to provide 300 kW output power with up to 10% of all RF-PAs either in a failed or inhibited state for an indefinite amount of time with no negative impact on the expected lifetime of any of its components due to sub-optimal operation conditions. If more than 10% of RF-PAs fail, the SSPA can continue operating if it is deemed safe to do so, and if it does not exceed any of the Soft or Hard Limits for the SSPA. The SSPA output power shall degrade linearly up to 50% of failed/inhibited RF-PAs.

Apart from the redundant operation described for the RF-PAs above, the SSPA shall not have single points of failure in any of its Amplifying Stages, i.e. the SSPA must remain operational even

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if at least one unit of any of its Amplifying Stages fails or is inhibited. Isolated RF combiners are preferred but not required.

3.1.6 Power supplies

The Contractor can select power supplies so long as the SSPA characteristics comply with the requirements as specified herein. Redundancy shall exist. Like the RF-PA devices, the selected power supplies must be modular, i.e. several units must together provide the necessary total DC power to the RF-PA devices. A single failure shall not inhibit the entire SSPA. It is of the utmost importance to have a design which is reliable, requires minimal maintenance, and enables easy replacement of faulty modules/components. The controls shall operate on BSA supplied 120 VAC. The main power supplies shall operate on BSA supplied 208 VAC 3-Phase. The 208 VAC 3-Phase will be 4 wires plus GND. The SSPA shall be protected against damage if the AC voltage is out of range.

3.1.7 Earth Connections

3.1.7.1 Chassis Earth Connections

A threaded ¼”-20 earth bolt shall be provided on the rear of each chassis within the racks. Each chassis shall have its own earth ground cable connected to the rack.

3.1.7.2 Rack Earth Connections

A threaded ¼”-20 earth bolt shall be provided on the top of each rack.

3.1.8 Control System 120 VAC Switch

An on/off switch for the Single Phase 120 VAC supply that powers the Control System, and a circuit breaker must be present inside the Control System Rack.

3.1.9 Internal Energy Dissipation

In the event of an interlock or command that forces the SSPA into a lower machine state (see Section 3.2.11), the SSPA must be able to discharge all its stored thermal and electrical energy in

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a safe and controlled manner. Access to the interior of the SSPA shall not be granted unless there is evidence that energy from the AC and DC systems are within safe thresholds.

3.1.10 SSPA Reliability (MTBF)

The SSPA shall have a predicted MTBF of greater than 10,000 hours in an environment subject to all possible combinations of values defined in Table 2. The units of all Amplifying Stages shall have a predicted MTBF greater than 35,000 hours.

3.1.11 Temperature Limits

3.1.11.1 Temperature Limits on Exposed Surfaces

The temperature on any touchable surface shall be less than 48.89 °C (120 °F). A touchable surface is defined as any surface that can be accessed without the use of tools.

3.1.11.2 RF Device Die Temperature

The maximum die temperature of LDMOS RF Devices shall not exceed 130 °C over the entire load space, dynamic range, and range of environmental conditions. Gallium Nitride (GaN) RF Devices die temperature shall not exceed 150 °C over the same circumstances outlined above.

3.1.12 RF Hardware Requirements

3.1.12.1 RF Switch

There shall be a high-speed RF switch at the input of the SSPA that shall shunt the input RF to a 50 ohms termination when the SSPA is not in the RF ON state. The purpose of this switch is to quickly terminate the input RF signal in the event of a fault condition. The rise/fall time of the RF Switch shall be between 100 ns and 500 ns.

3.1.12.2 Thermal Protection

Temperature sensing shall be fitted to heat-generating devices in the SSPA to provide equipment protection if internal temperatures exceed allowable limits.

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3.1.13 Water Cooling

Water cooling will be provided by BSA. The SSPA shall incorporate water cooling to ensure that the components within the SSPA stay within their thermal limits. A minimum of 80% of the heat generated by the SSPA shall be removed by water cooling. The water shall exit through a flow meter for each water-cooled rack. There shall be a drain valve at the bottom of each rack to drain the water. The cooling system shall be designed such that very little water remains trapped after draining. The cooling system shall tolerate input cooling water with an input pressure of at least 150 psi (as per Table 2). The cooling system total pressure drop shall be no greater than 40 psi. Required flow rates (maximum, minimum, nominal) for operation shall be defined by the Contractor.

3.1.14 Air Cooling

In addition to water cooling, the SSPA may incorporate air cooling to dissipate up to 20% of the total heat generated. If required, air shall be drawn in through vents at the front of the chassis and expelled at the rear of the chassis. Air filters shall be fitted to any required fans. Fans and air filters shall be affixed in such a way that they can be easily replaced without the need to remove chassis from the racks.

3.2 SSPA Control System Specifications

3.2.1 Programmable Logic Controller (PLC)

The SSPA must have a local, industrial-level commercial Programmable Logic Controller (PLC) to handle:

- The SSPA state machine (see Section 3.2.11).
- All critical SSPA variables and parameters.
- All internal warning/fault/interlock signals.
- Communication with the Remote Control and any other sub-controllers inside the SSPA.

The power supplied to the PLC and all other communication subsystems must be derived from the 120 VAC Single Phase source.

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3.2.2 Communication Interface and Protocols

All SSPA variables from the AC distribution, DC converter/power supply, RF, cooling, and safety systems must be made available to the Remote Control system via an Ethernet (RJ-45) connection. The SSPA control system shall interface with the Remote Control system via one or more of the following communication protocols:

- Modbus/TCP.
- Ethernet/IP.
- OPC-UA.

3.2.3 External Interlocks

The SSPA control system must be able to accommodate for the handling and processing of external interlocks that come from the Remote Control system. The interlock connectors shall be located inside of the rack. The connector type shall be a 2-Pin Phoenix Contact, Male, Feed-through Header, Type DFK-MSTB.

3.2.4 Status Connections

The four status connectors shall be located inside of the rack. The connector type shall be a 2-Pin Phoenix Contact, Male, Feed-through Header, Type DFK-MSTB.

3.2.5 RF ON/AC OFF Status Connections

The four RF ON/AC OFF Status connectors shall be chassis isolated BNC type female connectors.

3.2.6 Local Protection

Table 6 lists the Local Protection features that the SSPA must provide. All features must be reported to the Local and Remote Control systems. All features must also trigger a Summary Fault and/or Summary Warning.

Table 6: SSPA protection features

Warning	System Action	Reset Required
RF Device Over Current Warning	1. Remain in RF ON state	N

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The current being drawn a RF Device is excessive	2. Inhibit RF Device 3. Report location	
RF Device Failure Warning *A RF Device is blown or damaged*	1. Remain in RF ON state 2. Inhibit RF Device 3. Report location	N
Thermal Warning *The temperature is excessive*	1. Remain in RF ON state 2. Report location	N
VSWR Warning *The VSWR is excessive*	1. Remain in RF ON state 2. Report location	N
Maximum RF Forward Power Warning *The forward power is excessive*	1. Remain in RF ON state 2. Report location	N
Air Flow Warning *Fan failure or low flow rate*	1. Remain in RF ON state 2. Report location	N
Water Flow Warning *The water flow rate is too low*	1. Remain in RF ON state 2. Report location	N
DC Power Supply Warning[4] *A DC power supply voltage is out of range*	1. Remain in RF ON state 2. Report location	N
SSPA Input Overdrive Warning *The RF input power is excessive*	1. Keep RF ON state	N
SSPA VSWR Fault *The VSWR at output of the SSPA is excessive*	1. Go to DC ON state	Y
SSPA Maximum RF Forward Power Fault *The RF forward power at the output of the SSPA is excessive*	1. Go to DC ON state	Y
SSPA Thermal Fault[1] *The temperature is excessive*	1. Go to AC ON state 2. Report location	Y
SSPA Water Flow Fault *The water flow rate is too low*	1. Go to AC ON state 2. Report location	Y
SSPA AC Power Fault *The 208 VAC voltage is out of range*	1. Go to AC OFF state	Y
Auxiliary DC Power Supply Fault *Auxiliary DC power supply voltage is out of range*	1. Go to AC OFF state	Y
RF Device Redundancy Fault[5]	Go to STANDBY state	Y

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[4] A DC power supply is defined as: any one power supply delivering power to the drain of RF Devices.
[5] The RF Device Redundancy Fault shall trip when the sum of the following exceeds the maximum limit:
a. Number of RF Device Failure Warnings
b. Number of RF Device Over Current Warnings
c. Any other warning which results in a RF Device being inhibited.

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3.2.7 AC Contactor Actuation

The SSPA control system must be used to electronically actuate on an AC Contactor that shall be present on the AC distribution system. The AC contactor must be connected to the PLC through a dry contact. The following interlocks must immediately trigger the release of the AC contactor:

- Smoke.
- Water leak.
- Open cabinet doors.
- CRASH Switch (see Section 3.2.8).

Once disabled, the AC contactor must only be enabled again locally through the control system Human-Machine Interface (see Section 3.2.10). Suitable circuit breakers for each phase must also be installed before the AC Contactor.

3.2.8 CRASH Switch

The SSPA control system must have a CRASH Switch on its control system rack. It must be implemented as a large, red button, and it must always be responsive, both in Local and Remote operation. It must latch mechanically once triggered and must be only locally reset. Pressing this button must trigger an interlock and a transition to the machine AC OFF state (see Section 3.2.11.2). This interlock must only be cleared locally. The CRASH Switch must be physically located between 3 and 5 feet above ground.

3.2.9 Internal Protection

The SSPA control system must be able to detect faults and locally protect all its subsystems against damage from, but not limited to:

- Excessive input RF power.
- Excessive temperature readings.
- Inadequate air flow.
- Inadequate water flow.

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- Out-of-range 3-Phase, 208 VAC, or Single Phase, 120 VAC voltage readings.
- Inadequate environmental parameters, such as, but not limited to, ambient temperature, humidity, and atmospheric pressure.

3.2.10 Local Human-Machine Interface (HMI)

The SSPA must have a local Human-Machine Interface (HMI) located on its control system rack. The HMI must have a Graphical User Interface (GUI) that is controlled by a dedicated server/computer. The GUI program must be accessible remotely, and it must display:

- Current machine state.
- Visual indications for all alarms, warnings, and interlock status.
- Measurements from the AC distribution, DC power supply, and RF.
- Controls to reset interlocks while in local mode.

3.2.11 SSPA state machine

A state machine must be implemented to handle the state of the SSPA. The machine state must consist of the following states:

- AC OFF
- AC ON
- DC ON
- RF ON

The state machine state must be always be indicated visually by a 4-tier tower light (green, yellow/orange, red, and white) mounted on top of the SSPA. The white LED must be turned ON if the SSPA has a warning or fault. The description for each one of these states is defined in the following sections.

3.2.11.1 AC OFF state

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In the AC OFF state, the SSPA control system shall be operational, and the AC distribution system shall be disabled through the AC Contactor switch. All the fans present in the AC distribution system must be turned off. This state must be visually represented by a flashing red light. A transition to and from this state will follow the AC Contactor Actuation logic described in Section 3.2.7.

3.2.11.2 AC ON state

In the AC ON state, the SSPA control system must be operational, the AC distribution system shall be enabled through the AC Contactor switch. The DC power supplies must be disabled, and the RF Switch must be open, i.e., connected to a 50 ohms termination. The assigned color for this state is green. In this state, the following conditions must be met:

- Control system is active.
- Amplifier power switch is off (ACDC power supplies are off).
- RF Switch is open.

3.2.11.3 DC ON state

In the DC ON state, the DC power supplies are enabled, and the RF Switch must be open, i.e., connected to a 50 ohms termination. The SSPA can only be in the DC ON state if all the following conditions are simultaneously met:

- All rack doors must be closed, and their respective interlocks must be cleared.
- Some, or all external interlocks must be cleared.
- The Emergency Stop interlock must be cleared.
- The AC Contactor is enabled, and its related interlocks must be cleared.
- Water flow is OK, and its related interlocks must be cleared.
- Water inlet temperature and pressure are OK, and its related interlocks must be cleared.
- Fans power supplies are OK, and their related interlocks must be cleared.

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- Control system power supplies are OK, and their related interlocks must be cleared.
- RF-PA temperatures are OK, and its related interlocks must be cleared.
- DC power supplies are OK, and their related interlocks must be cleared.
- Cabinet doors are closed, and their related interlocks must be cleared.
- All communication with controllers is OK, and their related interlocks must be cleared.
- Cabinet temperatures are OK, and their related interlocks must be cleared.

3.2.11.4 RF ON

In the RF ON state, all the conditions mentioned in the DC ON state must be met, and the RF Switch is closed. The RF Switch can only be closed from the DC ON state, and all external interlocks concerning the machine operation must be cleared. Any internal or external interlocks will trigger transitions to either AC OFF, AC ON or DC ON states, depending on which respective interlock were triggered.

3.2.12 LED Status Indicators

In addition to the 4-tier tower light described in Section 3.2.11, the status of the SSPA shall be indicated locally by a LED array on the front of the Control System rack. The LEDs shall indicate important aspects of the operating status, fault/warning status and control signal status. In general, a simple color code shall apply, whereby a white LED indicates a fault/warning condition, and a green LED indicates a normal condition. The machine status LED colors and behavior should follow that of the 4-tier tower light, that is:

- Red for RF ON.
- Yellow/orange for DC ON.
- Green for AC ON.
- Flashing red for AC OFF.
- White if the SSPA has warning/faults.

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3.2.13 Local/Remote Operation

The SSPA control system must allow for both local and remote operation. A Local/Remote switch must be available on the control system rack. It must be implemented through a physical key that may be removed from the SSPA. Changing between Local and Remote will not trigger a transition between machine states.

3.2.14 Data Time Stamping and Sampling Rate

All data shall be made available for remote monitoring with time stamp that has 1 millisecond of accuracy. The controller shall synchronize its time-of-day clock over ethernet using an NTP server.

3.2.15 Runtime Hour Meter

There shall be a runtime hour meter to monitor the accumulating run time operating hours. The meter shall record all time while the SSPA in the RF ON state. It shall be non-resettable. The range shall be 0 – 99,999 hours (minimal). The display shall be located on the front of the rack.

3.2.16 Remote Status Monitoring and Reporting

All status data shall be accessible through the remote interface and shall include:

- SSPA current state (AC OFF, AC ON, DC ON, and RF ON).
- SSPA Local/Remote switch state (Local, Remote).
- All interlock states.
- All faults and warning status shall be accessible through the remote interface. The status shall include the fault/warning physical location(s).
- SSPA first fault condition (reports original/first cause of the SSPA fault).
- Controller shall capture and store at least 1000 entries of each of the following status in a nonvolatile circular buffer. All entries shall include time stamp with at least 1 millisecond of time accuracy. Any number of entries shall be read on request via remote interface:
    - SSPA first fault history (first cause for SSPA fault condition)

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- SSPA fault history capturing any fault, warning, internal & external interlocks.
- SSPA machine state history which includes cause/reason for the transition between states. It shall clearly indicate the action that caused the SSPA to transition between states.

3.2.17 Network Interface Configuration

3.2.17.1 Ethernet Configuration

Both Dynamic Host Configuration Protocol (DHCP) and STATIC Ethernet configurations shall be supported.

3.2.17.2 MAC Address

The network interface's MAC address shall be displayed or printed on the control panel.

3.2.17.3 IP Address

The configured IP addresses shall be displayable on the control panel on a digital display.

3.3 RF-PA Specifications

The RF-PAs must be easily swappable for routine care, maintenance, and repair. If the total weight of the RF-PA is more than 40 pounds, the Contractor must provide dedicated tools and equipment to assist with the handling, moving, and installation of the RF-PA.

The following parameters of each RF-PA must be monitored and handled by the control system:

- Gate voltage of all RF Devices gate terminals.
- Drain voltage of all RF Devices drain terminals.
- Drain current of all RF Devices drain terminals.
- RF Device die temperature.

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The RF Device die temperature may be indirectly inferred from a sensible temperature reading taken at a suitable spot close to the RF Device. The Contractor must explain the inference process and elaborate on systematic and random uncertainties.

3.4 Local RF Instrumentation Specifications

The SSPA must provide sample signals (channels) from critical RF signals for local RF instrumentation. The sampled signals RF power must be (10 ± 0.5) dBm at nominal, and they must be available from female type-N connectors. All RF instrumentation channels must be isolated from one another and from the main RF line path with an isolation of at least 30 dB. The critical RF signals that must be available for local RF instrumentation are:

- SSPA output forward RF power
- SSPA output reverse RF power
- SSPA input forward RF power (before RF Switch)
- SSPA input reverse RF power (before RF Switch)
- Output forward RF power after all Amplifying Stages

3.4.1 Digital RF Power Meter

There shall be a digital power meter to monitor the forward and reflected power of the SSPA. The accuracy shall be 2.0% into 50 ohms over the entire dynamic range. Power shall be displayed in kilowatts. The display shall be located on the front of the rack. Power monitoring shall also be available to the Remote Control system.

3.5 RF Patch-Panel Specifications

The SSPA must provide sample signals (channels) from critical RF signals for the LLRF System (LLRF) through a RF patch-panel that must be located on the top side of the SSPA rack. The sampled signals RF power must be (10 ± 0.5) dBm at nominal, and they must be available from female type-N or SMA connectors. All RF instrumentation channels must be isolated from one another and from the main RF line path and from the Local RF Instrumentation signals with an isolation of at least 30 dB. Different directional couplers must be used to sample the RF patch-

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panel signals and the local RF instrumentation signals. The critical RF signals that must be available for the LLRF System are:

- SSPA output forward RF power
- SSPA output reverse RF power
- SSPA input forward RF power (before RF Switch)
- SSPA input reverse RF power (before RF Switch)
- Output forward RF power after all Amplifying Stages

3.6 Code/Standard Compliance

3.6.1 Electromagnetic Compatibility

The SSPA should be designed to be compatible with the following EMC regulations in force, and should neither be perturbed nor perturb other installations according to these regulations:

- EMC Immunity: IEC 61000-6-2.
- EMC Emissions: IEC 61000-6-4.

It shall be assumed that throughout this specification, unless explicitly detailed separately for a given parameter, each SSPA is treated as Class A, Group 1 equipment. The corresponding conducted and radiated limits should be understood, and design practices applied accordingly.

3.6.2 Electrical Code

The SSPA shall be designed following the below electrical codes:

- 29 CFR 1910 Subpart S – Electrical
- NFPA 70E-2021
    - Article 340 (Power Electronic Equipment),

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- Article 350 (Safety Requirements for R&D Labs)
- Article 360 (Safety Requirements for Capacitors)

- UL 508

Except for UL 508, all other referenced standards are required to be implemented.

3.7 Construction Specifications

The racks shall be constructed to allow for the use of a pallet jack or forklift which will be used to move the racks into their final locations. The center of gravity shall be indicated on each rack. The amplifier will be installed into the existing RF gallery presently housing the tetrode tube amplifiers. All required support facilities are available. The available installation area for the 350KW SSPA is a 10’ x 12’ floor space of unlimited height.

3.8 Environment, Safety and Health (ESH)

Identification of hazards, and their mitigation, shall occur during all stages of the life of the Equipment including; installation, commissioning, operation, maintenance, and repair. Identification of means to eliminate or manage each hazard shall be provided based on the following hierarchy:

- Substitute with something less hazardous, or
- Engineer – mitigate the severity of the hazard, or
- User Personal Protective Equipment (least desirable).

4 VERIFICATION

Appropriate inspection/tests shall be performed to ensure equipment conforms to all requirements in section 3 of this specification.

4.1 Classification of Inspections

Items covered by this specification shall be subjected to the following tests to determine compliance with all applicable requirements:

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4.1.1 Acceptance Tests

- Contractor Acceptance Test
- Factory Acceptance Test at Contractor Site
- BSA Site Acceptance Test

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