Power outage resilience & recovery – Control System (EED)

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03/02/2024 - Power outage timeline

- 12:14 am – Fault on 230kV line due to storm weather conditions

- ~1:00 am – Cryo operator noted their generator was not running
  - Result was that the IOC servers and stand-alone OPI went down – these are needed for EPICS monitoring and control of cryoplant equipment. Once down, restoring these IOCs and EPICS services requires B005 to be functional.

- ~ 1:00 am – RF team onsite to manually detune SC cavities from klystron gallery, done ~ 7:00 am

- ~ 3:00 am – Cryoplant and B005 (for controls computing infrastructure) powered up on 60 kV line

- ~ 4:30 am – Controls computing system expert begins recovering network systems and servers
  - This is a minimum 2-hour task that requires experts onsite

- ~ 5:00 am – EED engineer onsite to start up cryomodule insulating vacuum system

- ~ 6:00 am – Central control system functionality restored, Cryoplant IOCs recovered
  - Full recovery took several days, and we're still finding lingering issues

Issue 1 – Risk of damage to Cryomodules

- If the SC cavities are not detuned when the cryomodule temperature rises they can be physically damaged.
    - A team of 5 (Sonya, Sebastian, Jorge, Jing, ?) were in the gallery for approximately 6 hours (1 am – 7 am), manually detuning the cavities
    - Work was made more difficult due to the loud ODH alarms going off the whole time
    - **Recommendation: Find out if they can detune themselves if power is lost**

- The Cryomodule insulating vacuum leak means a fast rise in pressure and loss of thermal insulation when pumps are off, resulting in venting helium within a few hours (especially L3)
    - Insulating vacuum turbo and backing pumps in tunnel, PLC in gallery for local control through HMI.
    - This outage, Shawn was in the gallery for several hours to manually start them. Since several hours had passed the vacuum was already very high so the pumps were overheating with the load. Crossed fingers and hoped the pumps didn't die (they didn't – this time). No spares. L0, L1, L2 each have a single cart, L3 has remaining 6. Each cart also has a CCG and GP, turbo, roughing pumps – parts about $50K plus labor to assemble and test since they're custom.
    - **Recommendation: If PLC and pumps were on generators they could continue running without the central control system. PLC and turbo pumps are 110V, but the backing pumps are 208V in the tunnel so would require additional special infrastructure to support use of generator.**

Issue 2 – Risk of damage to Cryoplant, loss of helium

- Cryoplant CCI included plan to keep EPICS IOCs running, and one OPI workstation available in the cryoplant control room in these conditions – provided power is supplied by their generator.

- Once the power is lost, the IOCs rely on the common infrastructure in B005 to boot up.
  - This was the case on March 2. The cryoplant had power on 60kV line for several hours but were unable to control equipment needed to try stabilizing the system or recovering helium.

- **Recommendation 1: Make sure the cryoplant generator is reliable.**

- **Recommendation 2: Have B005 on generator so once cryoplant has power the EPICS IOCs and workstations will be able to boot properly (if they lost power).**

- **Recommendation 3: Completely remove cryoplant dependency on accelerator control system.**
  - The PLC HMIs were abandoned. The system is too complex to control one piece of equipment at a time.
  - Suggest implementing more industrial solution like Ignition. Server and client applications (UIs, alarms, archiving) could all be hosted locally at cryoplant. Could easily maintain an EPICS layer in parallel.

Issue 3 – Control System Computing Recovery

- System team onsite to confirm power to B005 is stable, the breakers are on, and the HVAC is running. If not, they require assistance from electricians or F&O before they can start.

- Next, they restores services following a procedure:
  - Recover routers, then NFS, then DNS/DHCP network services
  - Next, they bring up the main servers and OPIs, checking that each boots correctly – these are needed for IOCs to start
  - Complication with services that rely on OCIO – authentication and remote log in servers, Oracle, Elog, etc.
  - Need additional help from others to restore archivers, directory service, etc.

- Controls engineers recover all IOCs and equipment in the gallery and service buildings
  - Big problem that equipment often gets power before NFS, TFTP, DNS/DHCP are available, so they hang and need to be prompted or rebooted later to come up correctly. This can take a day or two since there are several hundreds.
  - Most IOCs can be recovered remotely after the servers boot, but several need local intervention to recover
  - Some crates refuse to power cycle remotely.

- **Recommendation: B005 on backup generator**
  - Existing generator by building is not sufficient quality.
  - Need new quote for new generator suitable for computing centers, like what B050 uses. Quote from 2021 was $200K.

Issue 4 – Control System Hardware damage and recovery

- Power outages usually result in damaged controls hardware equipment
  - Usually lose CPUs and other equipment in racks – sensitive to the power coming back on which is why we pre-emptively turn them off for planned power outages.
  - Some power sensitive equipment is long out of production, and we are running short on spares.

- Even if equipment isn't damaged, recovery takes days
  - Motion team needs several days in the tunnel to recover undulator controls (especially HXR)
  - Some systems are complex and need expert intervention, which can be difficult off hours.

Issue 5 – Other items with operational impact

- PPS IOCs needed to be restored quickly in order for Operations to control PPS zone security.

- Gun Vacuum – NC already on a generator and UPS, SC gun has NEG so passive. Longer timescale here until damage.

- Laser – motion recovery ~ 1 day. Had to unplug some piezos while power was off so they didn't come up and cause damage to optics. Should disable itself safely when power off

- Timing, MPS, BPM, RF, and more systems required the SMEs to recover IOCs and settings
  - Ongoing NFS/autosave issue made some of this more difficult

- Site air needs to be up for valves to move

- Power outage expose existing problems (time bombs?) so we need to have a better way to confirm systems are ok

- We need more remotely-controlled power switches to power cycle equipment

List of (mostly) associated caters - CTL

CATER Id	Subsystem	Status	Created Date ↓₌	SLAC Division	Active Jobs	Active Sol/Task	Assigned To	Area	Shop	Short Description	Group
168812	Mps	Closed	03/04/2024 15:01	TEC			Mock, Jeremy A	INJECTOR WEST	CTL	Reset MPS Laser Heater Shutter. Requires access to S0 and QLO to open the enclo	LCLS
168809	Other	New	03/04/2024 13:54	TEC				ACR	CTL	FEE/NEH/XRT BSOICS EDM Panel shows the trip status for BSONEH08 is green when th	LCLS
168808	Wires	Scheduled	03/04/2024 13:46	TEC	1			LINAC MIDDLE (S10-20)	CTL	FACET LI20 PMT3060 voltage readback jumped by ~250 V after 3/2 power outage. Unc	FACET
168778	Bpm	Closed	03/04/2024 08:57	TEC			Hoobler, Sonya	UND	CTL	In-tunnel BPMS:UNDH:5190 receiver chassis is offline	LCLS
168777	Undulator	Review to Close	03/04/2024 08:46	TEC			Thayer, Tom	UND	CTL	Undulator HXR and SXR power outage recovery	LCLS
168771	Bpm	In Progress	03/04/2024 07:44	TEC			Hoobler, Sonya	INJECTOR WEST	CTL	the BPM in CM01 behaved un-normally a few days ago. We saw the Y position stuck	LCLS-II
168770	Other	Scheduled	03/04/2024 07:15	TEC	1	1		LCLS-INJ	CTL	Inj Vault Gun UPS, TS/R UPS for battery failure?	LCLS
168769	Atca	Closed	03/04/2024 06:54	TEC			Vu, Thuy Mong	UND	CTL	Recover ATCA systems after power outage for all service buildings including UND	LCLS-II
168768	Atca	Closed	03/04/2024 06:52	TEC			Vu, Thuy Mong	LINAC MIDDLE (S10-20)	CTL	Recover ATCA systems after power outage SEC10--SEC20. Including FACET crates.	LCLS-II
168767	Atca	Scheduled	03/04/2024 06:49	TEC	1		Vu, Thuy Mong	LINAC WEST (S1-9)	CTL	Recover ATCA systems after power outage SEC00-SEC09	LCLS-II
168759	Computer	New	03/03/2024 14:42	TEC				LINAC EAST	CTL	cannot connect to cpu-in20-pm01-mgt	LCLS
168753	Atca	New	03/03/2024 12:53	TEC				UND	CTL	ATCA crate shm-undh-sp03-2 does not ping	LCLS
168752	Atca	Scheduled	03/03/2024 12:51	TEC	1		Vu, Thuy Mong	LINAC EAST	CTL	Recover ATCA systems after power outage. Will write individual caters for crate	LCLS
168749	Atca	New	03/03/2024 12:43	TEC				LINAC MIDDLE (S10-20)	CTL	ATCA crate shm-bpn17-sp01-1 does not ping	LCLS-II
168748	Atca	New	03/03/2024 12:43	TEC				LINAC MIDDLE (S10-20)	CTL	ATCA crate shm-bpn16-sp01-1 does not ping	LCLS-II
168747	Atca	New	03/03/2024 12:43	TEC				LINAC MIDDLE (S10-20)	CTL	ATCA crate shm-bpn15-sp01-1 does not ping	LCLS-II
168746	Atca	New	03/03/2024 12:42	TEC				LINAC MIDDLE (S10-20)	CTL	ATCA crate shm-bpn14-sp01-1 does not ping	LCLS-II
168744	Atca	New	03/03/2024 12:42	TEC				LINAC MIDDLE (S10-20)	CTL	ATCA crate shm-bpn13-sp01-1 does not ping	LCLS-II
168740	Atca	New	03/03/2024 12:40	TEC				LINAC WEST (S1-9)	CTL	ATCA crate shm-l3b-sp04-1 does not ping	LCLS-II
168739	Atca	New	03/03/2024 12:39	TEC				LINAC WEST (S1-9)	CTL	ATCA crate shm-l3b-sp01-1 does not ping	LCLS-II
168738	Atca	New	03/03/2024 12:38	TEC				LINAC WEST (S1-9)	CTL	ATCA crate shm-l2b-sp01-1 does not ping	LCLS-II
168737	Atca	New	03/03/2024 12:35	TEC				LINAC WEST (S1-9)	CTL	ATCA crate shm-bc1b-sp01-2 does not ping	LCLS-II
168736	Network Infrastructure	New	03/03/2024 12:32	TEC				BSY	CTL	ts-mcc0-nw04 in general does not seem to work correctly. Not showing any ioc co	LCLS
168735	Network Infrastructure	Closed	03/03/2024 12:13	TEC			Granieri, Charles D.	BSY	CTL	eioc-bsy0-mp02 not connecting properly to terminal server.	LCLS
168733	Computer	New	03/03/2024 12:01	TEC				LINAC EAST	CTL	acsw-li27-nw03 will not connect to control system.	LCLS
168732	Mps	Closed	03/03/2024 12:00	TEC			Mock, Jeremy A	LINAC EAST	CTL	LN 16 (eioc-li26-mp01) needs to be power cycled. The remote tools to do so are	LCLS
168731	Computer	New	03/03/2024 11:58	TEC				LINAC EAST	CTL	Cannot remotely control acsw-li26-nw03	LCLS
168730	Atca	New	03/03/2024 11:54	TEC				BSY	CTL	ATCA crate shm-sps-sp05-1 does not ping	LCLS-II
168726	Camac	New	03/03/2024 11:22	TEC				LCLS	CTL	3/2/24 power outage fallout LI23 CR1 AND cr4 look offline.	LCLS
168725	Computer	Closed	03/03/2024 11:19	TEC			Harms, Michael JJ	LINAC EAST	CTL	fallout 3/2/24 power outage IOC:LI23:CV01 will not boot.	LCLS
168723	Computer	New	03/03/2024 10:43	TEC				LCLS	CTL	Following 3/2/24 power outage, feedback IOC SIOC:SYS0:FB01:HEARTBEAT status is f	LCLS
168722	Timing	Closed	03/03/2024 10:33	TEC			Bong, James	LCLS	CTL	Fallout from 3/2/24 power outage, LCLS-NC EVG IOC IOc:GBL0:EV02 will not boot.	LCLS
168721	Mps	New	03/03/2024 10:27	TEC				ACR	CTL	Fallout from 3/2/24 power outage, the following LCLS-Cu MPS link nodes are not h	LCLS
168710	Vme	New	03/02/2024 12:10	TEC				LINAC MIDDLE (S10-20)	CTL	FACET Area VME problems.	FACET
168709	Vme	Closed	03/02/2024 11:57	TEC			Harms, Michael JJ	LINAC EAST	CTL	IOC:LI24:IM01 not booting after power outage.	LCLS
168708	Network Infrastructure	Closed	03/02/2024 11:55	TEC				LINAC EAST	CTL	ACSW:LI21:NW05 not connecting to network after power outage.	LCLS
168707	Vme	Scheduled	03/02/2024 11:53	TEC	1		Harms, Michael JJ	LINAC EAST	CTL	CRAT:LI25:BP01 has intermittent bad V3, 3.3v	LCLS
168706	Vme	Closed	03/02/2024 11:33	TEC			Harms, Michael JJ	LCLS-INJ	CTL	LLRF VME IOC's not booting after power outage: IOC:IN20:RF01 IOC:IN20:RF04 IO	LCLS

SL

List of (mostly) associated caters - SWE

CATER Id	Subsystem	Status	Created Date ↓≡	SLAC Division	Active Jobs	Active Sol/Task	Assigned To	Area	Shop	Short Description	Group
168805	Camac	New	03/04/2024 13:35	TEC				LINAC EAST	SWE	Subbooster standby trigger TMSK, TDES, and TCTL do not get restored when the CAM	LCLS
168801	Dc Magnets	Closed	03/04/2024 12:41	TEC			Le, An	LINAC MIDDLE (S10-20)	SWE	After issuing a standardize command to the BC14 bend string, the bends do not sh	FACET
168799	Rf	Closed	03/04/2024 12:30	TEC			Condamoor, Shantha	EBD-FEE	SWE	XTCAV HXR and SXR SLED chillers are offline.	LCLS
168796	Motion Control	In Progress	03/04/2024 12:26	TEC			Balakrishnan, Namrata	LINAC MIDDLE (S10-20)	SWE	DSOTR E224 Laser Mirror LVDT appears to be disconnected	FACET
168781	Edm	In Progress	03/04/2024 09:51	TEC			Garnier, Chris	LCLS-INJ	SWE	Master Source alarm limits are lost after power failure or reboot of IOC: WATR:	COMMON
168772	Camac	In Progress	03/04/2024 08:13	TEC			Hoobler, Sonya	LINAC EAST	SWE	CAMAC timing data has been lost fot LI25 and LI28.	LCLS
168766	Rf	New	03/03/2024 23:28	TEC				LCLS-INJ	SWE	Several PADs in IN20 seem offline. Unable to power cycle them remotely via AC	LCLS
168743	Pydm	Closed	03/03/2024 12:42	TEC			Myers, Chris	SOFTWARE	SWE	FBCK LI30 Main Page on pydm / lclshome still has a button to launch edm page	LCLS
168741	Pydm	Closed	03/03/2024 12:41	TEC			Myers, Chris	SOFTWARE	SWE	FBCK LI29 Main Page on pydm / lclshome still has a button to link to edm version	LCLS
168734	Pydm	In Progress	03/03/2024 12:05	TEC			Agrawal, Devan A.	SOFTWARE	SWE	pydm lclshome crashes when it feels like it when using it from lcls-srv01.	LCLS
168729	Computer	Closed	03/03/2024 11:51	TEC			Brobeck, Kenneth C.	SOFTWARE	SWE	sioc-sys0-nw01 does not seem to follow systemctl commands on lcls-daemon1.	LCLS
168728	Rf	In Progress	03/03/2024 11:39	TEC		1	Condamoor, Shantha	LCLS-INJ	SWE	IOC IN20 RF04 and RF06 will not boot up.	LCLS
168727	Epics Infrastructure	In Progress	03/03/2024 11:37	TEC			Summers, Tasha	LCLS-INJ	SWE	ACSW:IN20:NW06 is not responding to commands.	LCLS
168718	Edm	Closed	03/03/2024 09:59	TEC			Brobeck, Kenneth C.	ACR	SWE	Can't load BTH East PPS camera from the PPS BTH Diagnostics Panel.	LCLS
168716	Computer	Closed	03/03/2024 08:48	TEC			Brobeck, Kenneth C.	OTHER	SWE	PPS camera for EBD-FEE not launching from panel - web version working fine	COMMON
168712	Computer	Closed	03/02/2024 17:25	TEC			Brobeck, Kenneth C.	OTHER	SWE	Some PPS cameras (LI24, BSY Manway, BTH East, EBD/FEE) are updating slowly on VL	COMMON