Electrical HPO Training Facility For NPPs

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1. Introduction

- Performance improvement for NPP personnel through training is crucial for maintaining plant safety and reliability.
- High level of workforce competency promotes quality and safety culture hence eliminating incidents/events by human errors
- Thus, we define the requirements and design the facility for the HPO training of NPP electrical workforce.

2. Design requirements analysis

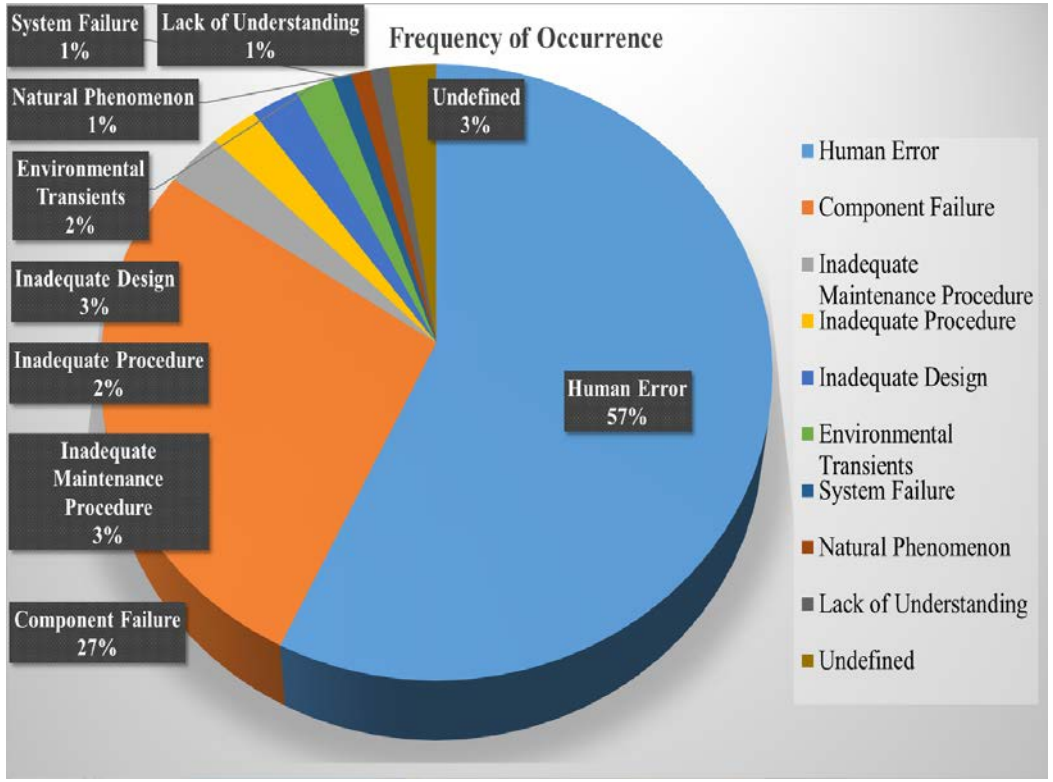
2.1 General Design Requirements

- HPO facility is designed to meet the measurable objectives of the HPO training plan and manual.
- shall be designed to perform representative operation of the medium voltage (MV) motors for the engineered safety feature actuation systems (ESFAS)
- Operation conditions : - normal
  - abnormal
  - emergency.
- monitoring and recording trainee's actions during interaction and training session with the HPO facility shall also be provided for in the design

2.2 Design requirements analysis

❖ from *NRC 2000-2020* **LERs** and **FMEA** reports analysis; 200 electrical failures were analyzed by their cause.

S/N	Cause of Failure	Frequency of Occurrence	%
1	Human Error	114	57.0
2	Component Failure	55	27.5
3	Inadequate Maintenance Procedure	6	3.0
4	Inadequate Procedure	5	2.5
5	Inadequate Design	5	2.5
6	Environmental Transients	4	2.0
7	System Failure	2	1.0
8	Natural Phenomenon	2	1.0
9	Lack of Understanding	2	1.0
10	Undefined	5	2.5
	Total	200	100



3. System Architecture

- The HPO training facility is the functional and physical replica of the actual **4.16 kV power distribution system for medium voltage (MV)** motor and non-motor load system in the NPP
- Shall have similar **equipment layout/arrangement** with the actual system
- Have **no new Human Factors Engineering** (HFE) issues that may impair training and cognitive skill development.
- Facility is designed to perform representative operation of the MV motors for **the ESFAS systems.**
- The HPO facility is a non-class 1E system.

3.1 Major Components

① ECMS

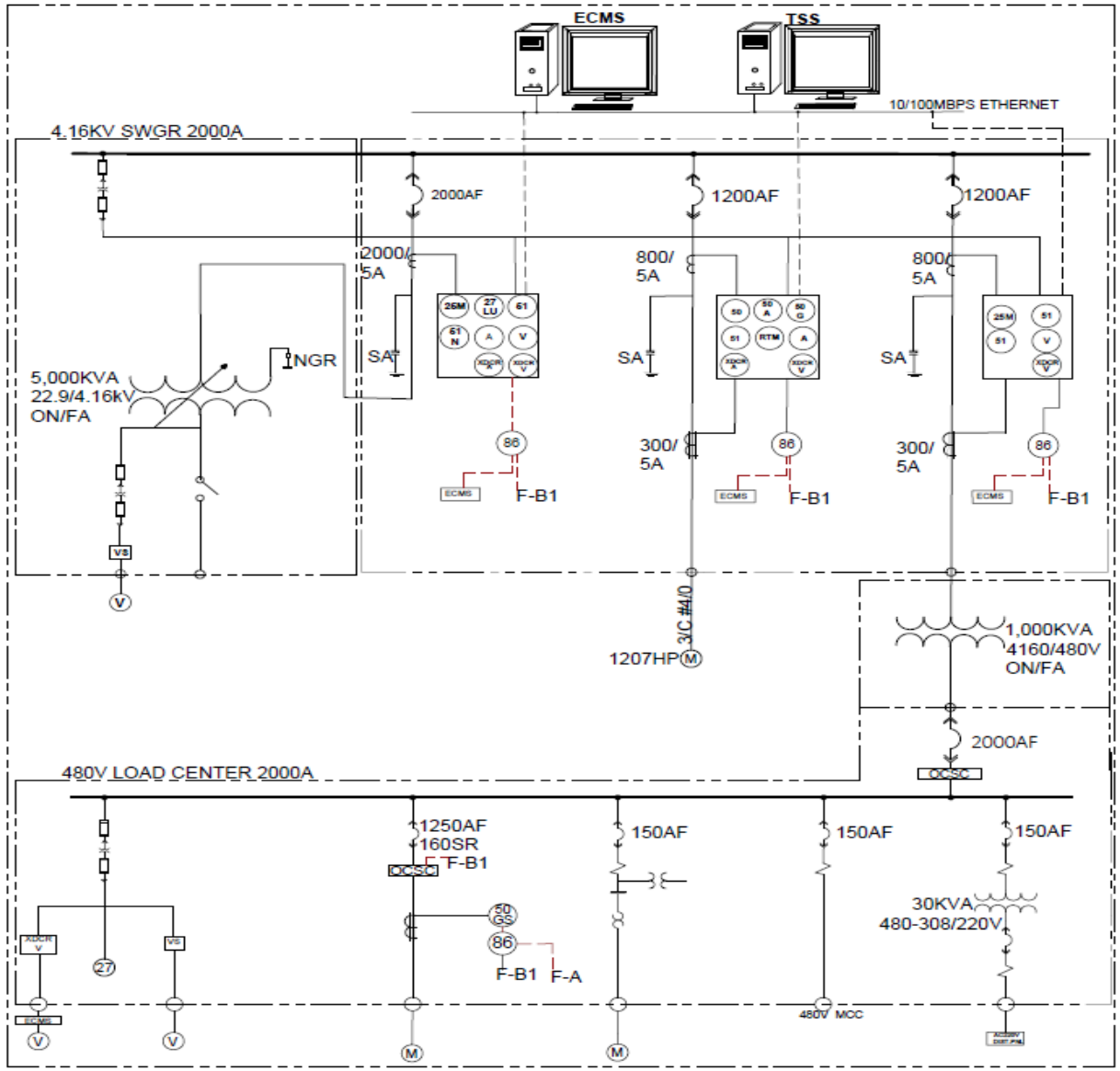
② TSS

③ 4.16kV switchgear

④ 480V Load center

⑤ Distribution transformers

- 5000KVA
- 1000KVA
- 30KVA



Single Line Diagram

3.2 System Architecture

1) 4.16kV SWGR

Consists of main bus, incoming feeder and outgoing feeders;

- All feeders are equipped with a vacuum circuit breaker (VCB) and digital protective relay.
- The CTs, VTs, ZCTs and surge suppressor (SS) are provided for each feeder as required.
- Each feeder is protected by dedicated relay, and VCB is controlled and monitored from ECMS.

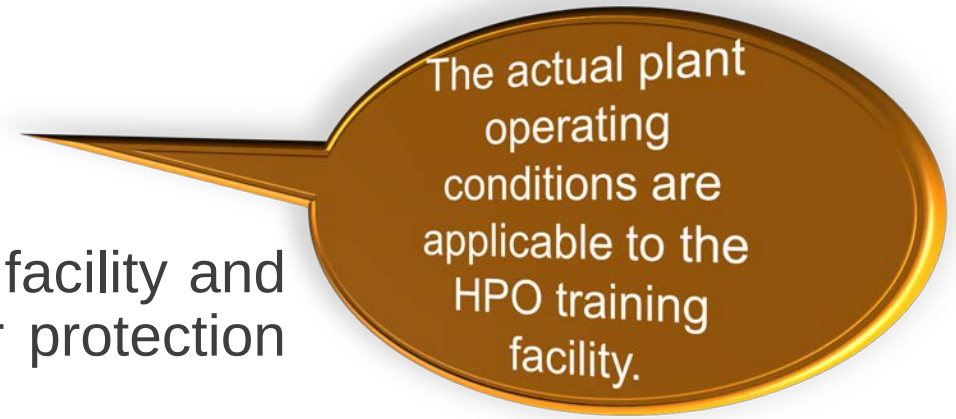
2) 480V SWGR

Fed from the 4.16kV SWGR and supply power to 460V motor load and 480V non-motor load.

Consists of main bus, incoming feeder and outgoing feeders

- Incoming feeder and one outgoing feeder are equipped with ACB.
- The outgoing feeder equipped with ACB supply power to 460V motor; greater than 60hp and smaller than 250hp.
- The other outgoing feeders are equipped with MCCB and supply power to the motor load not greater than 60hp or non-motor load not greater than 100kW.

- The 480V motor drives the lubrication pump of the 4.0kV motor. So the feeder breaker of 460V motor and the feeder breaker of 4.0kV motor shall be interlocked.
- It's configurable for abnormal scenarios and fault conditions observed in the actual plant to be simulated for the training purpose.



3) Training Supervisor Station (TSS)

- A TSS is designed as part of the HPO training facility and used to monitor the status of all the MV motor protection and control system.
- It's is designed to perform HPO training system control functions including initiation of system fault conditions

3) Training Supervisor Station (cont.)

The HPO training system control functions in the TSS include:

- Work instructions
- Protective relays set point modification
- Voltage level control
- Events monitoring and recording
- Fault conditions initiation

4. Design Verification and Validation

- Design document Verification is key after the facility design to check whether the requirements are fully satisfied.
- Requirements are classified into either MOE or MOP for the verification and validation of the system design.
- Provisions shall be made for seeding and simulating the hardware fault conditions in each component and module in the HPO MV motor protection and control system training facility.

1) HPO modules include;

- Component control (CC),
- Sequence control logic (SCL), for circuit breaker,
- Integrated motor protection relay (MPR),
- Electrical control and monitoring system (ECMS).

2) The hardware fault conditions include:

- Power supply failure or degradation
- Over load
- Short circuit fault
- Open circuit fault
- Ground fault
- Component Failure

3) ECMS, and MPR modules Simulations

The design shall allow for the following software fault conditions to be seeded and simulated:

- Logic failure
- Out-of-range operating parameter
- Digital processor failure
- Loss of communication

4) Human errors demonstrated in HPO

- Start and stop of motor
- Reacceleration of motor
- Trouble shooting
- Set point modification
- Fault reset
- Component repair or replacement
- Design vulnerability tracking
- Review and confirmation of discrepancy between drawing and installed component

5. HPO Electrical Training Scenario

- The scenarios provided in the training manual include the representative functional failure behavior of the MV motor protection and control systems.
- The scope covers the training assignments for the members of the training group identified in the HPO facility Hands-on Evaluation Plan which comprises the instructor, evaluator, and the trainees (Team leader, Worker A and Worker B).

Training Equipment

- HPO training equipment
- Video/Audio Recorder
- Time meter

Evaluation Tools

- SART (Situation Awareness Technique)
- NASA-TLX (National Aeronautics and Space Administration Task Load Index)

1) Role Play Training (RPT)

- Operator's human performance is measured and controlled using HPO facilities to properly maintain and achieve operation and maintenance in the role-playing practice.
- Participating personnel are:
  - Evaluators: HPO expert, ergonomic expert
  - HPO Instructor
  - HPO training facility evaluator

2) Debriefing

- The evaluator prepares and organizes the matters related to the problems simulated in the HPO facility.
- This is after conducting an in-depth discussion on the evaluation issues referring to the matters written by the evaluator, questions and questionnaires of the evaluator.

3) Practice and Evaluation

- Various situations are developed according to the scheduled scenario. Trainee performs the operation according to the situation of the HPO training facility.
- The evaluator records the specific matters while observing the trainee (action, conversation, etc.) with the current issues of the evaluation in mind.
- General evaluator determines if all measures for the planned scenario have been completed, then the evaluation is completed.

4) Practice scenario

- The scenario is written so that representative operation and maintenance tasks of HPO facilities can be performed using cases like of **sudden stoppage** of representative **4.16kV MV motor protection and control systems** and incidents of **ECMS failure**.

6. Conclusion

- Human-related events cause **>50%** of the electrical faults in NPPs. Hence, it's expedient to **optimize the performance** of electrical personnel working in the NPPs.
- This study elaborates the process and results of **design of electrical training facility for HPO,** designed according to **systems engineering approach** for the fulfillment of stakeholder requirements.
- The **HPO training facility** is an **exact replica** of the actual **MV** network in nuclear power plants hence suitable for the optimization of the NPP electrical personnel for the mitigation of the afore mentioned failures.


Thanks
to you all!