11 kV Switchgear Redesign
Sponsor: Chelan County PUD
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Abstract
Team Debussy was tasked with performing design, protection, and analysis of an 11 kV switchgear for a Chelan County PUD hydroelectric dam. Through studying the system, pros and cons of several different designs were determined. For the selected switchgear design, full fault and contingency analysis was conducted using ETAP and PowerWorld. Furthermore, optimal breaker ratings and specifications were determined. Arc-flash analysis was conducted on the proposed switchgear to determine hazard levels at each bus. Finally, full system protection was designed for the system, including CT/PT location and connections, bus differential protection settings, and optimization of existing generator and transformer protection relays.

Objectives
Team Debussy was tasked with the following objectives:
- State pros and cons of three alternative switchgear arrangements
- Generate breaker and disconnect ratings
- Assess arc-flash hazard levels at each breaker and disconnect
- Develop a bus differential protection circuit, including CT locations, ratings, and power relay settings
- Validate existing generator and transformer protection settings
- Mitigate arc-flash hazard levels to maximum of 8 cal/cm²

Switchgear Design

Design Factors:
Cost: Since the largest cost involved with switchgear are the breakers, the breaker quantity is the basis of our cost ranking. Being the most important factor for the public utility, it has a 1.5 times weight.
Reliability: The reliability ranking is based on how many elements need to be out of service (due to maintenance or fault) to lose the ability to provide power to either the grid or the critical fish pump.
Safety: The safety ranking is an evaluation of the ease and ability to safely remove equipment for maintenance and is down checked for any induced or unaddressed arc-flash concerns.
Complexity: The complexity ranking is based on the number of buses and protection elements required, allowing more opportunities for misoperation.

<table>
<thead>
<tr>
<th>Design</th>
<th>Cost</th>
<th>Reliability</th>
<th>Safety</th>
<th>Complexity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring Bus</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Open Ring</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>9.5</td>
</tr>
<tr>
<td>Main/Transfer Hybrid</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Final Switchgear Oneline:

Methodology
Simulator and HMI:
The protection scheme was tested using the SEL-AMS which simulates waveforms from current and potential transformers as low-level analog signals, allowing large fault values to be simulated safely. Using the SEL-5401 software, we programmed multiple fault conditions to verify the relay protection logic.

After the protection logic was validated, an HMI was created to display the system operation. The HMI was run using an SEL-RTAC which gathered relay information and displayed it for the operator. Under field conditions, the SEL-RTAC would function as a monitoring device, not performing individual protective actions. The SEL-RTAC also operates the ATS, which performs self-healing on the network.

ATS Control Logic:

Power Flow Analysis
ETAP: The general power flow analysis of the redesign was done using the power simulation software, ETAP. This allowed us to find critical operating values needed to select switchgear ratings, which included continuous and maximum fault current on each line in the design. This information allowed circuit breakers and current transformers to be chosen accordingly.

Arc-Flash Analysis: The arc-flash analysis of the system was completed using the ETAP software suite. The results provided the Energy Level using NFPA 70E standards, Arc-Flash Boundary parameters, Incident Energy, and Fault Clearing Time. From this information, warning tags can be placed near equipment to provide workers the information needed for them to safely work in the area.

Estimated Equipment Cost

Glossary
SEL: Schweitzer Engineering Laboratories
ATS: Automatic Transfer Switch
ETAP: Electrical Transient and Analysis Program
HMI: Human-Machine Interface
RTAC: Real Time Digital Simulator
AMS: Adaptive Multichannel Source

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Team Debussy