Study Committee B3

Substations and Electrical Installations

Paper ID: 10194

Semi-Autonomous Robot for Medium-Voltage Switchgear

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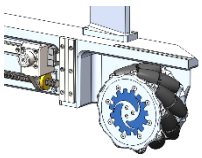
Motivation

- Create zero-harm environment for substation personnel.
- Moving breakers in and out of cubicles and around the substation has potential for harm.
- Arc flash may occur during racking process due to equipment failure or human error.
- Soft tissue injury may occur during moving breakers due to their weight - 400 kg or more - and tight spacing for maneuvering.
- No analogs were known to exist at the time of project commencement.

Driving

- Substation drawings and evaluation of floor conditions provided info for driving system design.
- Constrained spaces and the need for breaker alignment before racking it in the cubicle required omni-directional driving; mecanum wheels were custom designed for handling breaker weight.
- Uneven substation floors drove the use of suspensions for the wheels.

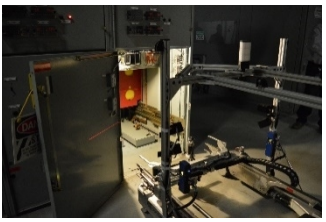


Securing Robot to Cabinet Frame

- Robot needs to be stationary when performing operations at the cabinet: racking breaker in and out, pushing and pulling breaker into and out of cabinet, and monitoring automated racking process.
- Cabinet latches were designed to keep robot frame secured to cabinet frame.

Experimental setup

Prototype robot was tested in a live substation on a cabinet with the live bus and with both, breakers and ground and test (G&T) devices.



Semi-Automated Breaker Handling

- Demonstrations of manual breaker racking at substation showed that heavy device on wheels makes alignment challenging; breaker and G&T Device designs were studied.
- Front plates on both devices were used for pushing/pulling action using a robot gripper.
- A robot elevator was designed to lift devices to simplify alignment of breaker side rollers with the cabinet rails.

Alignment

- Substation measurements showed that tolerance for breaker angular position is low – slight misalignment can cause jamming when breaker is pushed into the cubicle.
- Alignment is therefore needed between robot and cabinet and also elevating the breaker off the ground.
- Precise alignment must be automated since it is challenging for a remote operator to perform manual alignment using joystick or software controls.
- Accurate alignment of breaker to cabinet required the use of laser-based system, to determine position and orientation and a feedback system enabled changing robot position to align with both breaker and cabinet.

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Racking Process

- Racking nut on cabinet has variability in position due to fabrication method and years of use.
- A long, motorized socket tool with a guide for centering the socket on racking nut enabled consistent alignment of tool with racking nut.

Collision Avoidance

- Safety of robot, equipment, and personnel entail the use of sensors to detect collisions.
- Two LIDARs were used to obtain coverage overlap.

Remote Driving and Monitoring

- Numerous cameras are required to obtain different driving perspectives for the remote operator driving the robot.
- Narrow field-of-view cameras are mounted on the robot for identifying device (using tag ID) and monitoring of operations at the cabinet.

Unlatching breaker from Cabinet

- Similarities between breaker and G&T device enabled custom design of a single actuation system to unlatch breakers from cabinets before pulling them out.
- Solenoid actuated fingers push side levers of breakers upwards for the unlatching action.

Discussion

- Three tests were completed in a substation.
- All operations were demonstrated using the robot.
- Several robot modifications are necessary for improving reliability of operations.
- Changes need to be made to increase the range of motion of robot's moving parts, the laser-based alignment needs to be augmented to improve its reliability, and modifications are required to the latches for securing the robot tighter with the cabinet frame.

Conclusion

- Robotic devices are recommended to protect personnel employed in electricity generation, transmission and distribution processes.
- Breaker racking robot prototype designed, constructed and tested in live substation proved feasibility of developing robots to assist substation personnel performing tasks with potential hazards.
- Further investments and engineering efforts are required to commercialize breaker racking robot.