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A3 - TRANSMISSION & DISTRIBUTION EQUIPMENT
PS 3 / DIGITALISATION OF T&D EQUIPMENT

Automated Rack In & Rack out of 22kV/33kV AIS Breakers

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SUMMARY

In Transmission utilities 22kV & 33kV SF6 & VCB are used to cater the load to various consumer. Maintenance of this switchgear is very important to have reliable power supply and increased life of equipment, breaker outages are carried out for various maintenance activities. All existing 22kV & 33kV Air insulated switchgear (AIS) breakers are racked in & racked out manually as per the standard operating procedure. This task is carried out by the operational engineer using Arc suit. To enhance the safety of the operating activities, a pilot project done by team transmission & developed prototypes, Automated fixed type & Robotic Mechanism for rack in & rack out of 33kV AIS Breakers. This paper discusses the existing practice of 33kV AIS breaker isolation, and complete automated mechanism for isolation of breaker which is developed in-house & is in use at our receiving station.

KEYWORDS

Robot, Sensor, Encoder, Program - Logic - Controller, Tag - Reader, Radio - frequency, Personal - Protect - Equipment, Human - Machine - Interface, Variable - Frequency - Drive, Air - Insulated - Switchgear, Circuit - Breaker, Motor.

INTRODUCTION

The Tata Power Company Limited (TPCL) is the largest integrated private sector utility in the business of Power Generation, Transmission and Distribution in India. Transmission operations of Tata Power in Mumbai License Area is spread over the entire city of Mumbai and its suburbs, with more that 1125 ckt.km of transmission network & transformation capacity of 10500 MVA.

Breakers in Transmission can be classified as follows

1) Breakers with operating voltage levels of 220kV, 110kV, 33kV & 22kV
2) Indoor & outdoor breakers of Air insulated switchgear (AIS) & Gas insulated switchgear (GIS).
3) Medium of Arc interruption – Sulfur Hexafluoride (SF6), Vacuum.

22kV & 33kV Air insulated switchgear (AIS) Circuit breakers are racked in & racked out manually to carry out various maintenance activities such as breaker maintenance, work in CT compartment, cable compartment, work on power cable, or work at remote end. For all these activities, the breakers need to be isolated before carrying out any maintenance activity to work safely.

Presently all existing 22kV & 33kV AIS breakers are racked in & racked out manually as per the standard operating procedure. This task is carried out by the operational engineer using Personal protective equipment (PPE) such as Arc suit, Helmet & safety shoes. But this established methods of using PPE such as Arc suit, safety shoes and helmets have their own limitations due to the extend of damage the arc flash/ blast can cause to the operating persons.

During the rack out /rack in of breaker, arc occurs between breaker arm & live bus. In the event of breaker fault / mis alignement arc can be generated with arc flash temperatures can reach or exceed 35,000 °F (19,400 °C) at the terminals. The massive energy released in the event of fault rapidly vaporizes the metal conductors involved, blasting molten metal. The result of the violent event can cause destruction of equipment involved, fire, and injury not only to an electrical workers but also to bystanders. PPE such as arc suit are used to effectively shield a worker from the radiation of an arc flash, but that same PPE may likely be ineffective against the flying objects, molten metal, and violent concussion that the arc blast can produce.

An arc flash can cause minor injuries, third degree burns and potential death as well as other injuries including blindness, hearing loss, nerve damage and cardiac arrest. Fatal burns can occur when the victim is several feet from the arc. Serious burns are common at a distance of ten feet.

Current research shows that up to 80% of reported electrical injuries are caused by an electrical arc. This fact has generated safety requirements and industrial standards for switchgear defined by international and national standards.

Current Practice for Breaker rack in / rack out:

Use of PPE such as Safety shoes, helmet, Hand gloves and Arc suit are having its own limitations, as massive energy released in the event of fault can cause destruction of equipment involved, fire, and injury not only to an electrical worker but also to bystanders.

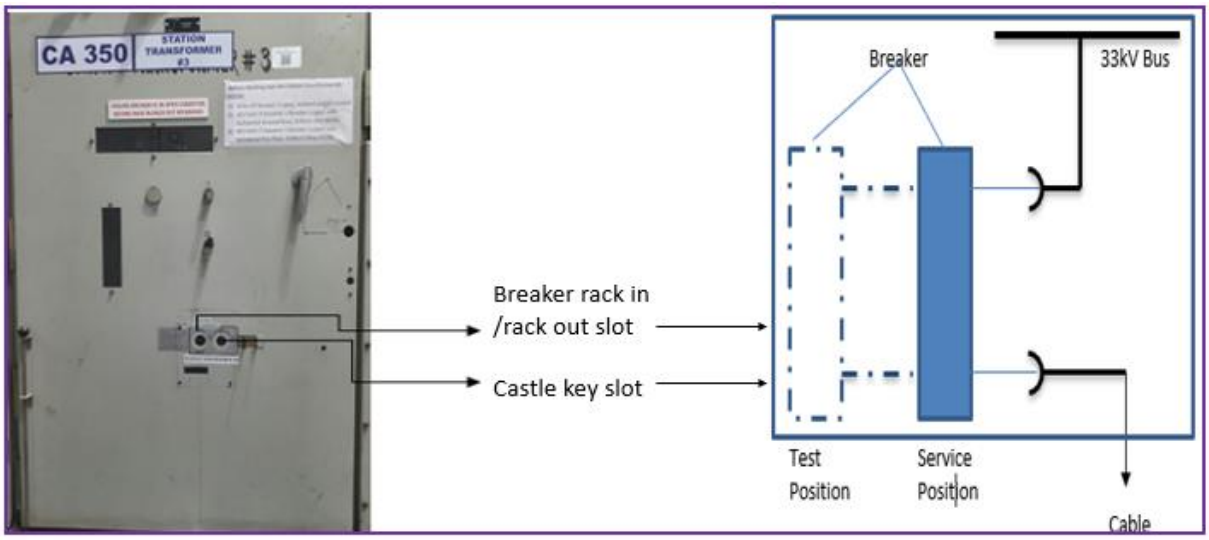

Figure-1 : Front view of Breaker & Side view of breaker with busbar (from left to right)

Figure-2: Operating person wearing Arc suit for carrying out rack in & rack out of breaker

Project-1:

Automated fixed type Rack in & Rack out device

To enhance the safety of the operating activities, a pilot project is taken up by Team transmission at our Receiving Station for developing a prototype for automated Mechanism for rack in & rack out of 33kV AIS Vacuum Circuit Breaker (VCB). To isolate the breaker, test/ service position key and manual handle for breaker movement are required.

This project is executed in three stages
Stage-1 : Breaker rack in & rack out through motor
Stage-2 : Test / service position key operation through motor.
Stage-3 : Interlock checking & integrated operation trials of both motors and development of android app.

Stage -1: Breaker rack in & rack out operation control circuit development & trials we have calculated & measured electrical and mechanical parameters during breaker rack in & rack out operations like speed, number of rotations and torque required for breaker movement. Whereas breaker test/ service position key is turned manually by the operating engineer. We have carried out extensive trials of breaker rack in & rack out of breaker with the motor & its control circuit. Breaker movement is divided in to three zones as mentioned in table 1.

Table-1: Technical parameters settings of motor for breaker movement

Zone	Description	Torque (Nm)	Speed	Rotations
Zone-1	Initial breaker movement from steady state.	30 Nm	40 rpm	0-15
Zone-2	To operate the shutter	15 Nm	40 rpm	16-32
Zone-3	Breaker arms contact with live bus.	35 Nm	40 rpm 2rpm (to avoid damage to breaker male female contacts)	32-39.2 39.3-40.2

Table-2: Motor specifications for Breaker movement

Pn	400W
Mn	1.27Nm
I max	7.8A
In	2.6A
Un	220V
Nm	3000 U/Min

Stage -2: Test /service position key operation control circuit development & trials
Different torque & angular movement settings are checked for key operation as per the breaker location (breaker at service or test position or in between).
Torque settings can be customized as per the breaker type. Depending on the distance between service and test position of breaker, settings can be incorporated as required.

Table-3: Technical parameters settings of motor for breaker movement

Key position	Angle (deg)	Torque (Nm)
Test- Intermediate	120 °	3 Nm
Intermediate- Service	70 °	3 Nm

Table-4: Motor specifications for Key movement

Motor	AC Servo Motor
Input	3 phase AC 76V, 1.1A
Rated output	0.1kW
Rated frequency	50Hz
Rated Revolutions	3000 rpm/ min
Cont. Torque	0.32 N-m

Stage-3: Incorporation of interlocks and integration of both motors for coordinated movement is achieved. Developed a user-friendly mobile app and integrated with the existing circuit and used wi-fi to communicate with the device from a safe distance of up to 100m. This control circuit is capable to prevent from operating when breaker is in closed condition.
Logic built to enable user to handle breaker emergency condition by suitable prompts such as “Recall the breaker either to Rack out position or Rack in position”.

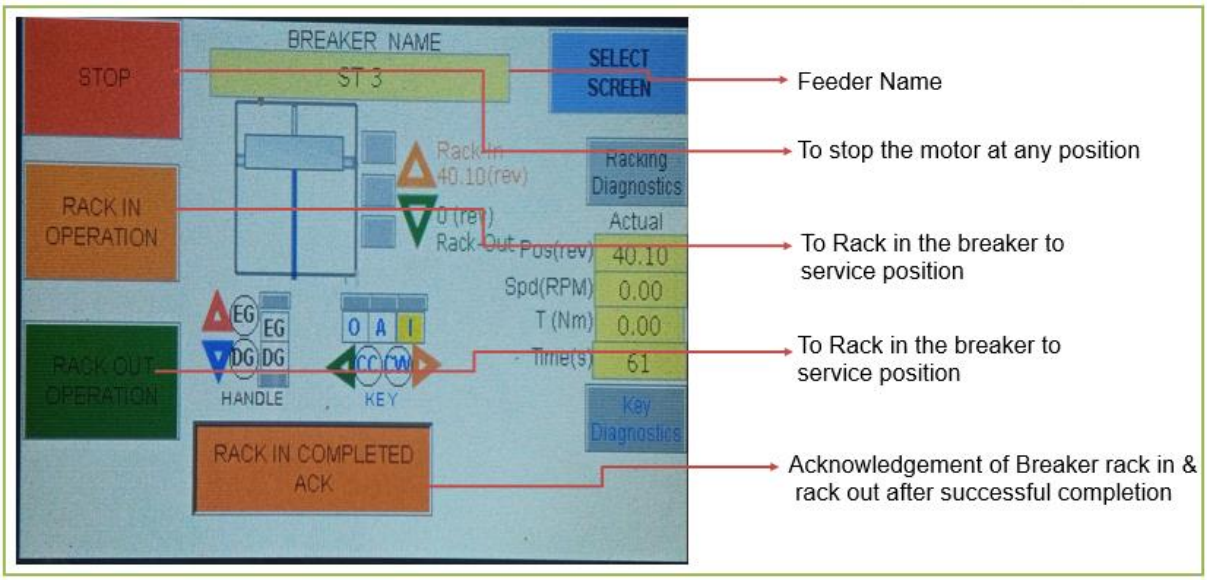

Figure-3 : Android app main display options

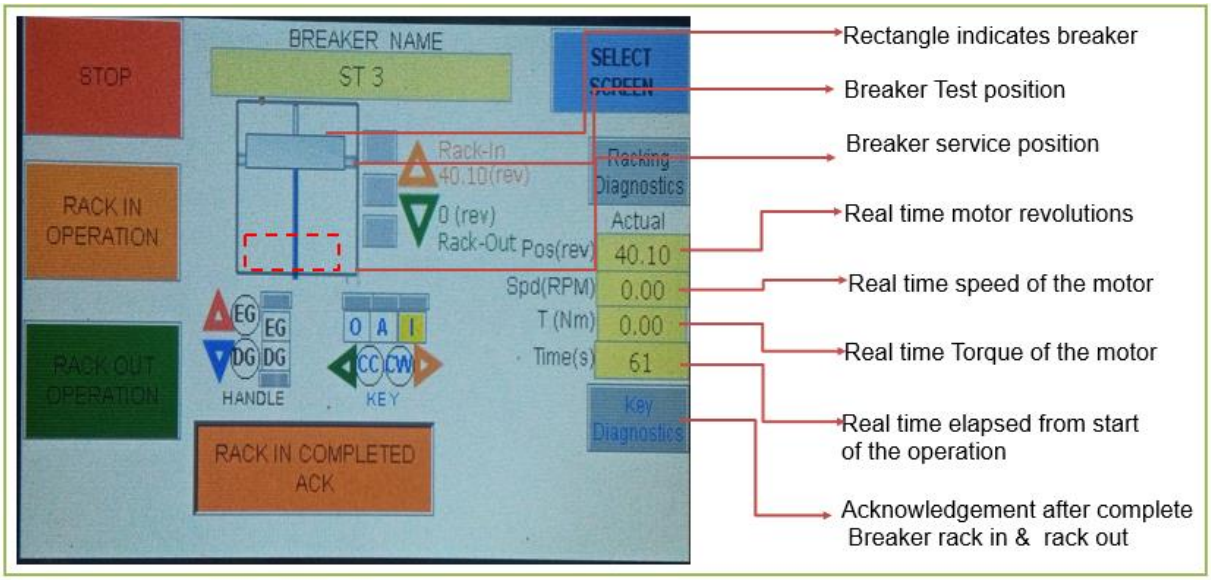

Figure-4 : Android app main display options

Working principle of Motor control circuit used for breaker movement

1) User can use mobile app/ Human-Machine Interface (HMI) display for performing task which will communicate to PLC.
2) Programmable logic Controller (PLC) issues command to Variable frequency drive of Castle key (VFD-1). Motor (M1) turn the castle key from 0 deg to 90 as per command from VFD-1 and encoder E1 sends feedback to VFD-1.
3) After receiving feedback from VFD-1, PLC will give command to Variable frequency drive of breaker (VFD-2), Motor (M2) will move the breaker to test / service position as per command from VFD-2 & Encoder E2 will give feedback to PLC through VFD-2.
4) PLC will again issue command to VFD-1 to turn the castle key from 90 deg to 180 deg in anti-clockwise direction. Encoder-1 will again give feedback to PLC through VFD-1, thus completing the breaker isolation. PLC will also communicate to Mobile app/ HMI, about isolation status of the breaker.

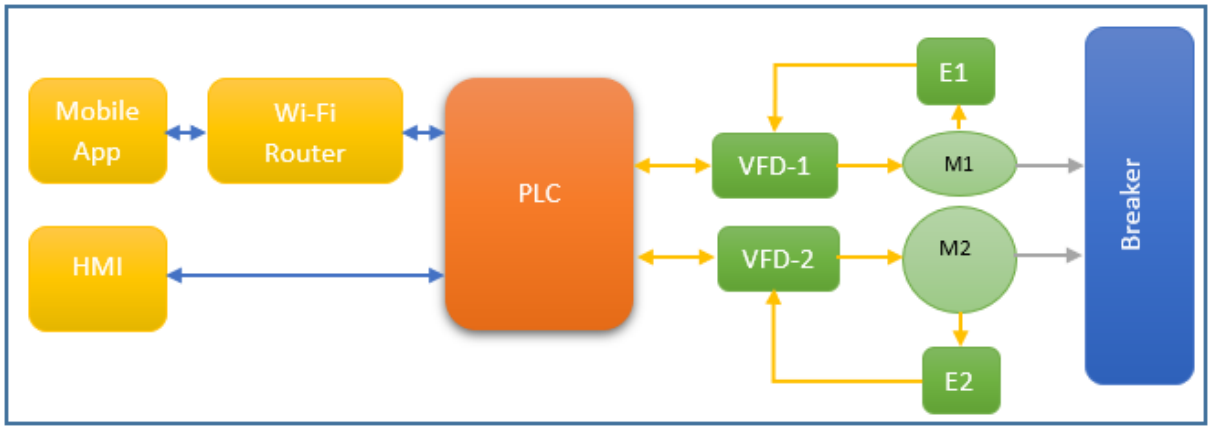

Figure-5 : Block Diagram for Control Circuit of motor used for Breaker movement.

Figure-6: Motors mounted on the breaker panel & Mobile app

Project-2: Robotic rack in & rack out of breaker

Single Robotic device is used to isolate any breaker on the bus as per the requirement of the user. The robot shall reach the desired breaker location as per the command issued by the user with the pathway tracker. Robot shall then read the breaker name plate and condition of breaker (ON/OFF) and then will align itself to rack out or rack in the breaker as per the current breaker condition.

- RFID tags & reader are user to identify the breaker location.
- Line sensors are used to guide robot to reach breaker and align.
- Proximity sensors are mounted on the robot to stop its sideward movement.
- With the help of actuator and slider, robot will align the motor with racking slot of breaker.
- Ultrasonic proximity sensor are used to detect any obstacle on its path.
- HD camera to have live visual on the dashboard.
- 2.4Ghz Wi-Fi module is used for communication over the internet.

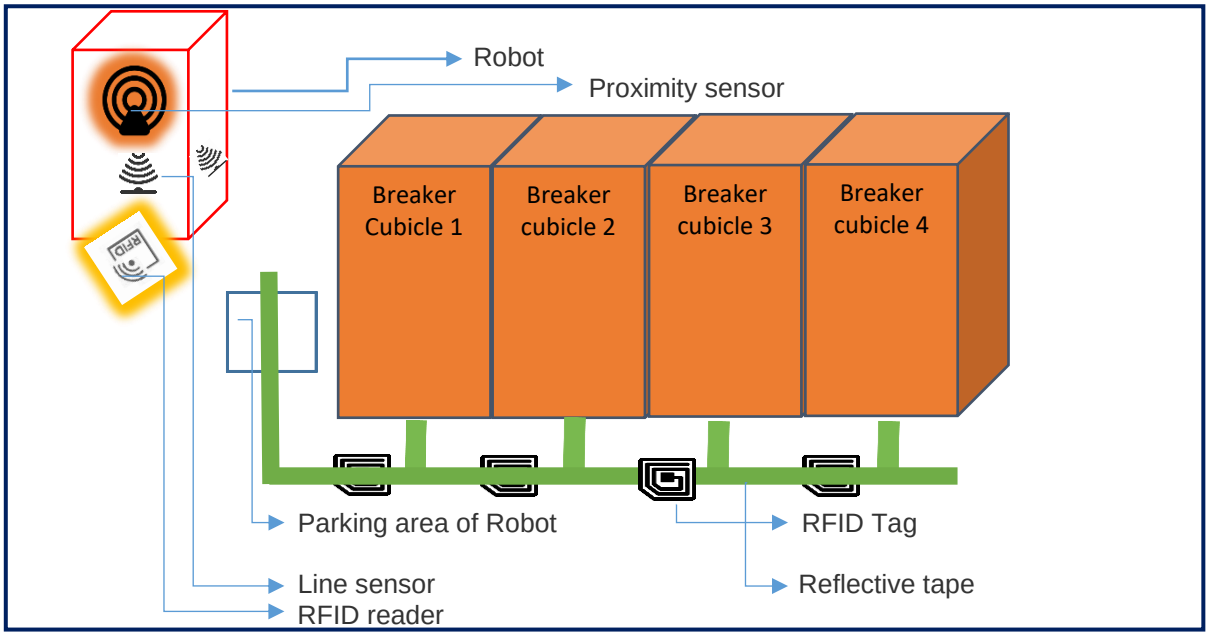

Figure-7: Block diagram of Main control circuit

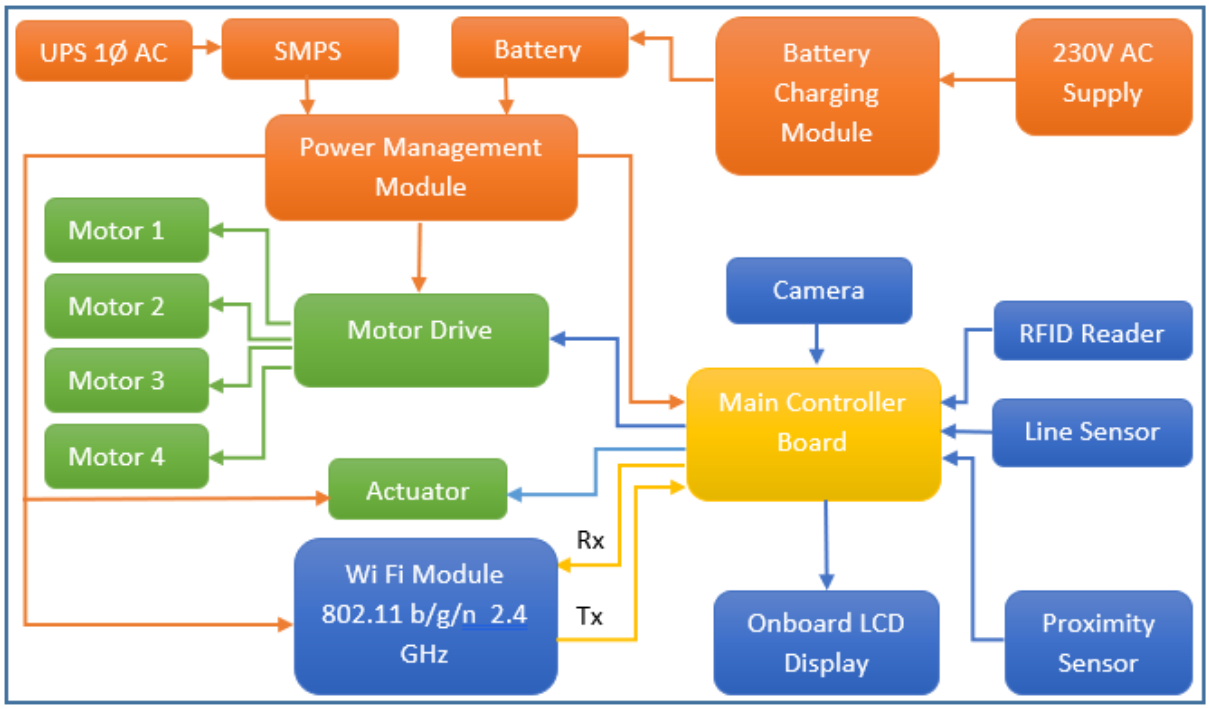

Figure-8: Block diagram of Main control circuit of Robot

Dashboard having the names of all breakers along with Live cam & controls of Robot are shown in figure 9.

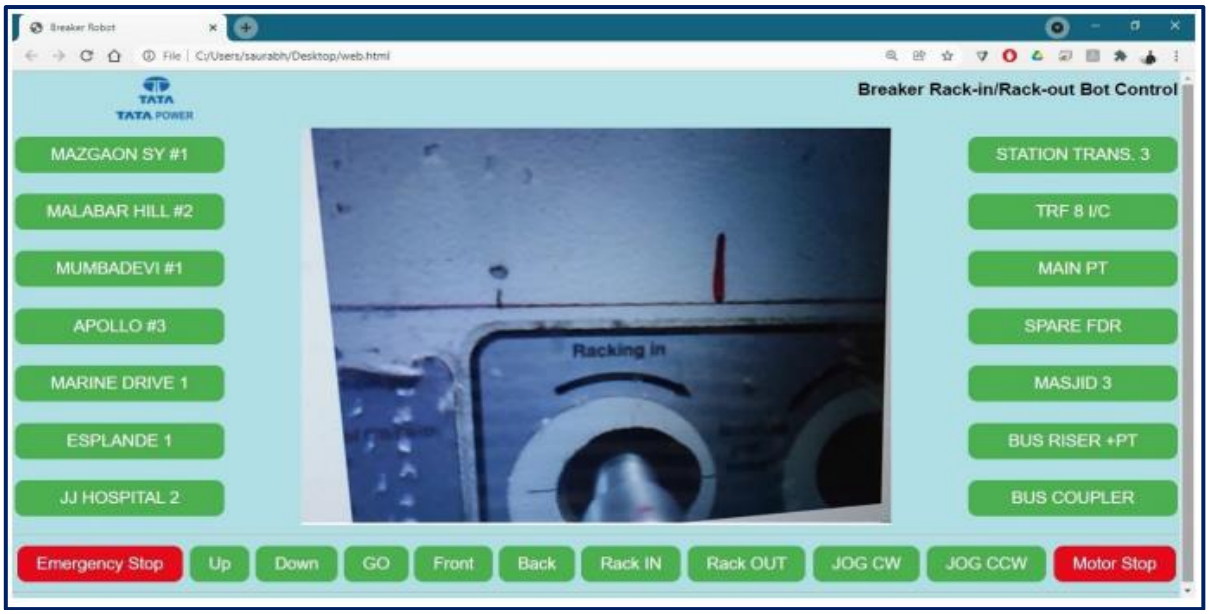

Figure-9: Remote monitoring and Control dashboard

Figure-10: Robot images in switchgear room

Major Challenges faced:

1) Excessive torques damaging the breaker arms
2) Excessive torques damaging the breaker drive mechanism
3) Accuracy of motor control
4) Incorporating interlocks to avoid wrong operation
5) Coordination between motors.
6) Robot reaching the desired breaker
7) Robot accurately accessing the breaker rack in & rack out slot.

Key Benefits:

1) Enhanced safety of the operating persons by carrying out isolation of breaker from safe distance.
2) Can be customized for similar AIS breakers
3) 75% Cost saving due to inhouse development.
4) Reduced outage time.
5) Shall improve customer satisfaction.
6) Camera on Robot gives live visual on Laptop/ Tab.
7) App indicates the real time position of breaker in the breaker cubicle.
8) Auto parking of Robot after carrying out isolation task
9) Robot works both on AC / DC supply.
10) Emergency stop button on Robot.
11) Warning flashlight & siren while Robot in motion.
12) Easy installation of RFID sensors, IR sensors and Pathway marking.
13) Single Robot can be configured to isolate 50 breakers with existing GUI.
14) App have multiple features which enables user to handle exigencies during breaker isolation.
15) User friendly interface to operate the robot and isolate the breaker.

Conclusion :

This project “Automated rack in & rack out of 22kV / 33kV Breakers “with engineering controls has created the safe working environment for operating persons of this breakers. Thus, preventing fatality**,** permanent disability, or harm to operating persons due to any untoward incident during breaker isolation.

We are currently using fixed type breaker rack in & rack out mechanism as well as robotic isolation of breaker at our receiving station. This project is planned to be executed at all our receiving station in Mumbai for horizontal deployment.

Following are the few notable advantages of the project.

- Automated rack in & rack out device shall rack out or rack in the AIS breaker with a single command using a user-friendly mobile app.
- Interlocks are incorporated to handle exigencies arising during the breaker rack in & rack out process.
- Three Zone torque setting for smooth breaker movement.
- Human intervention is not required as this device is mounted on the breaker cubicle.
- Single mobile application can handle up to 100 breakers
- Breaker isolation can be done from safe distance of 100mtr.Thus avoiding injury or fatality to the operating person in case of breaker damage during isolation process.
- Interlock is provided to prevent this device from operating when breaker is in closed condition.
- This device can be customized to isolate the breakers as per the requirements of the Utilities.

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