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PLC DESIGN FOR AUTOMATIC POWER TRANSFER OF 11KV SWITCHGEAR

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2.1 INTRODUCTION

An Automated Transfer System (ATS) is to provide automatic power transfers to groups reloading loads from common sources, such as utility services, to alternative sources, such as standby generation, in the event of a normal source failure. The project aims to develop a new design of an automatic power transfer system for the 11kV switchgear. Using the basic building blocks of utility power, system topology, on-site generation, and uninterrupted power supply, the basic role of the automatic transfer system can now be determined.

In this role, the Automatic Transfer System (ATS) must achieve two goals. First, the system must be stable where it should operate, even under abnormal power systems, without human intervention. Equally important, it must be able to distinguish when the system conditions do not guarantee transfer to alternate sources. Second, it must be able to control the switchgear as required and, in addition, be able to deliver accurate signal to the required alternative power sources (for example, to initiate start signal to the generator as soon as possible).

The switching controller will utilize the programmable logic controller (PLC) based on Omron programming software (i.e. CX-programmer). This function will be verified first in the simulation. To verify the effectiveness of the proposed approach, a physical simulator with real logic functions of the 11-kV switchgear system is used to demonstrate the proposed controller work for the ATS.

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2.2 BACKGROUND STUDY

Fault and outages on the electrical power are numerous and various origins which have an immediate impact on the industrial business and the life of people. It is true that no 100% secure power may be proposed, different specific and efficient concepts are available in line with the international and local standards and regulation to significantly increase the site reliability [1]-[3].

The resilience to electric power supply fault is done by providing adapted grid design, mapping the loads in secure paths, and implementing stand –by redundant power sources [4].

In this global picture, the Transfer Switch (TS) is the most common solution applicable in most of the electrical Industrial and Building networks from Low Voltage (400 V) to Medium Voltage (66 kV). An example of 415 V ATS structure which will be adopted in this project is illustrated in Figure 2.1.

When a failure occurs in a primary power system, the ATS invokes a standby power source, such as an uninterruptable power supply. An ATS can also start up more long-term backup power systems, such as local diesel generators, to run electric equipment until utility power is restored [5].

In Figure 1.1, the automatic transfer logic provides the decision-making for what automatic operations are to happen, and when. It controls the operation of the two transfer circuit breakers, **CB-UM,** and **CB-GM**, and receives status inputs from those breakers. It also can initiate generator start-up for the alternate power source.

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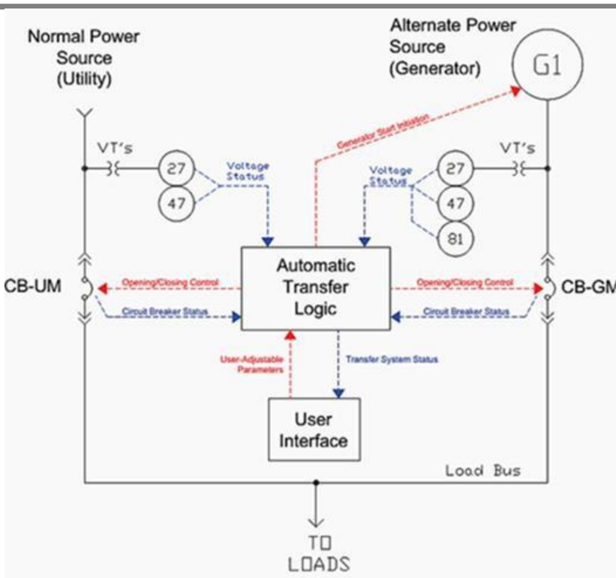

Figure 2.1: 415V ATS Design to be adopted for 11kV Supply System

2.3 METHODOLOGY

2.3.1 The System Hardware and Software

Omron PLC CJ2M-CPU33

PLC is being used in every process and manufacturing industries, apart from knowing the wires and connections, anyone should know the way to do PLC programs'-Programmable logic controller is an industrial solid-state computer that monitors input and output and makes logic-based decisions for automated processes or machines. OMRON has supported industry with innovative solutions and advanced technologies. Omron Programmable Logic Controllers (PLC) designed with high processing speeds and full transparency. Omron PLC's provide users with numerous functions and controls from small scale equipment to entire production lines. The Omron PLC CJ2M CPU33 is show in Figure 2.2.

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Figure 2.2: Omron PLC (Sysmac CJM-Series)

Programmable Power Supply

The Programmable Power Supply as shown in Figure 2.3 is the DC to DC converter used for main DC Supply in this project.

Figure 2.3: Programmable Power Supply

Auxiliary Micro Relay

Figure 2.4 shows the auxiliary Mod-Bus 485 relay used for dummy Circuit Breaker.

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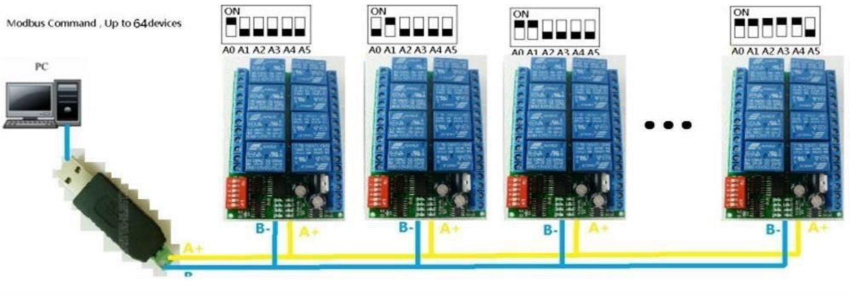

Figure 2.4: Auxiliary micro relay

CX-Programmer V9.5

CX-Programmer is programming software for all Omron's PLC series. CX- Programmer includes various types of features to accelerate the development of your PLC program. And this course is covering complete programming of PLC Model CP1E- E14DR-A of Omron PLC. This software is used for all the PLC series. And the instructions remain the same. This course will teach step by step How to make a Ladder Logics & Programming to any industrial process Control. The illustration of the programming show in Figure 2.5.

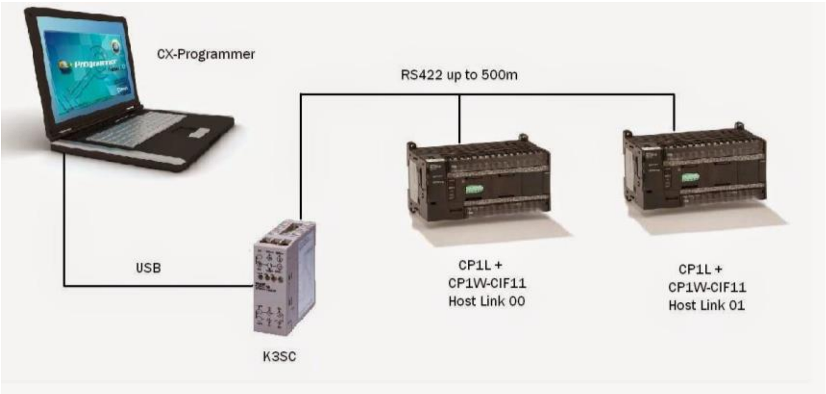

Figure 2.5: CX-Programmer Version 9.5 programming software

Human Machine Interface (HMI)

The HMI specification meant to describe proper development of an HMI panel. The specification is under development and should be referenced as it may have input for your HMI design. The HMI as shown in Figure 2.6 will be used for this project.

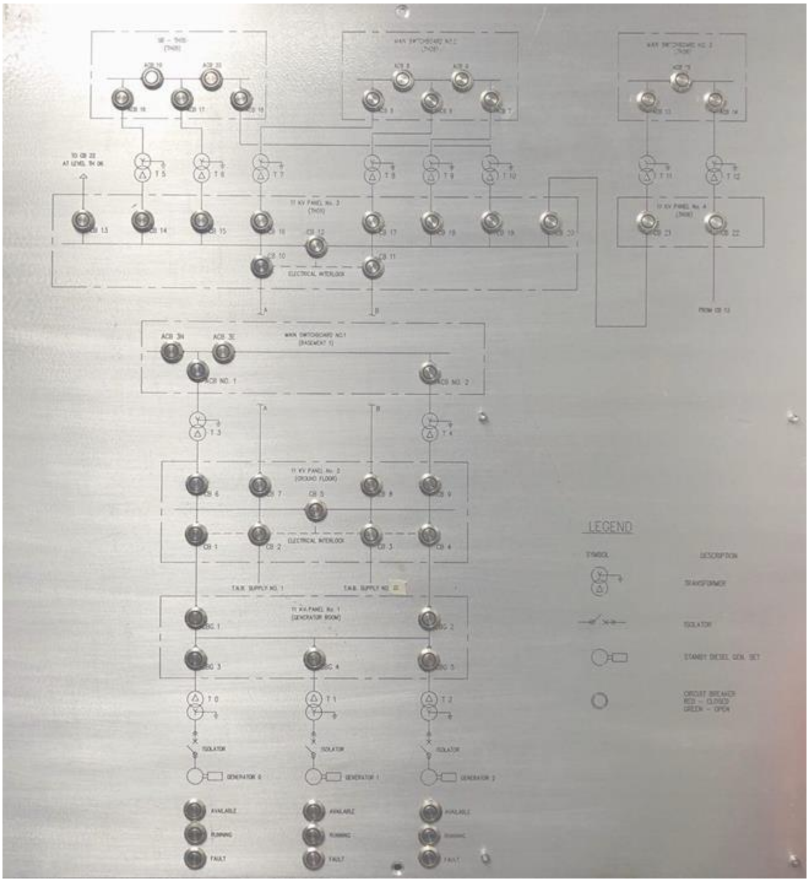

Figure 2.6: HMI for Single line Diagram of 11kV System

2.3.2. Circuit Schematic and System Design

The main role of the ATS is to recover power supply to the load after a failure of the utility supply connection or of a local generator supply. It is the common point of coupling between a failed and a safe source, thus it is critical to have a system reliable and responsive to any orders (manual or automatic) whatever the situations. But the ATS behavior can be different between two critical applications; the reason is the value the customer wants to prioritize:

- Safety: Prevent unexpected energization
- Service continuity: Ensure the load are always supplied

The transfer switch architecture is depending on the distribution network topology thus has got several configurations:

1/2 Transfer scheme

This is the standard case to transfer load from a main source to a backup source without bus coupling CB (Bus Tie). The electrical scheme of a transfer 1/2 is defined in Figure 2.7.

In normal operation, only one source is connected to the busbar and supplies the loads. When there is a loss of the 'main' source powering the busbar, the second source is connected which in turn supplies back the busbar. The scheme is shown in Figure 2.8.

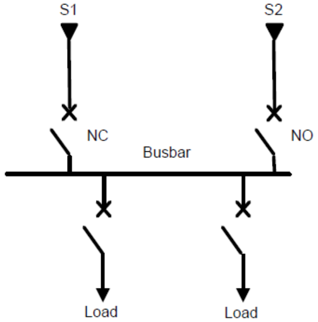

Figure 2.7: 1/2 Transfer scheme

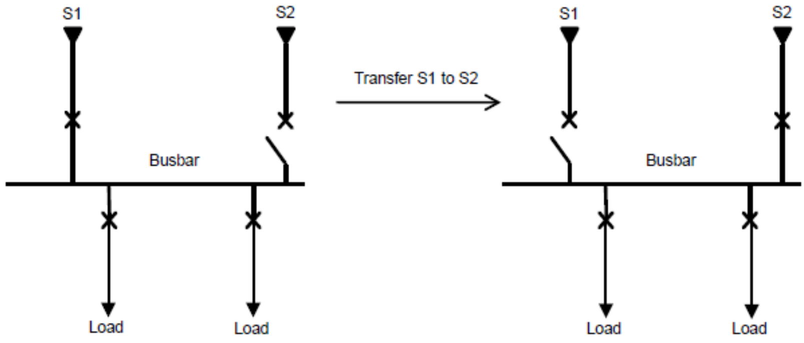

Figure 2.8: 1/2 Transfer scheme (S1 to S2)

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2/3 Transfer scheme

This is the most common electric scheme used for ATS case with a very efficient redundancy management as power source could be operated in parallel. The electrical scheme of a transfer 2/3 is defined in Figure 2.9.

In normal operation, the coupling circuit breaker (also called bus-tie) is in open position. Each source is powering half of the busbar. When there is a loss of one source powering a half busbar, the coupling circuit breaker is closed which in turn energizes the busbar with the remaining source, thus all the loads. The operation shown in Figure 2.10.

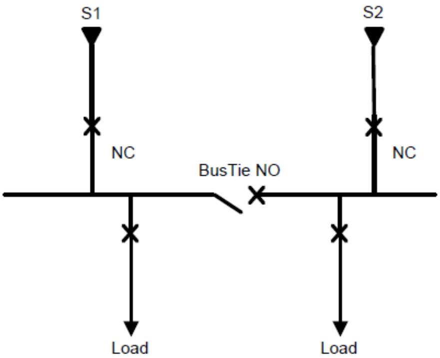

Figure 2.9: 2/3 Transfer Scheme

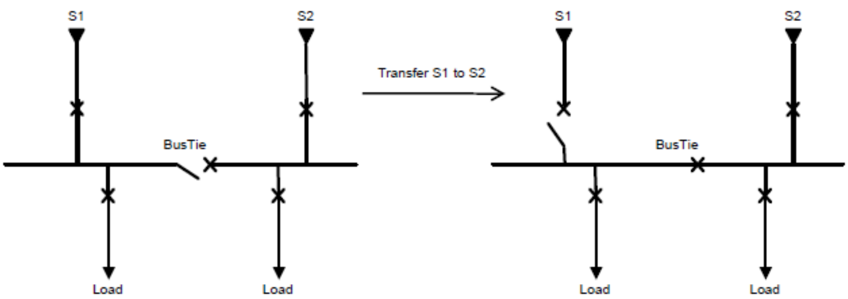

Figure 2.10: 2/3 Transfer Scheme (S1 to S2)

Multiple Transfer scheme

Other schemes exist for more complex topologies such as shown in Figure 2.11. One busbar is supplied with 3 sources (with or without

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coupling circuit breaker)

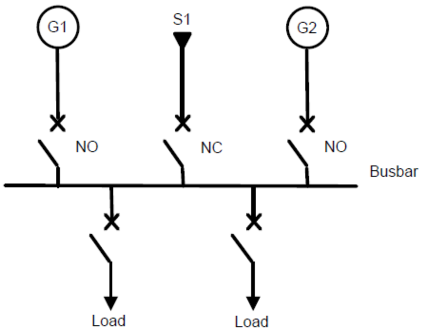

Figure 2.11: Multiple Transfer Scheme

The transfer switch is closely linked with the sources management generators). The connection of the generators in parallel with the utility (if allowed by the Utility grid code) imposes the use of a synchro-coupler device and an anti-islanding protection to isolate the industrial network.

As shown in Figure 2.12 the single generator can be connected using two variants. Both are valid however according to the rating power of the generator the preference is to have the ATS running in the electrical switchgear.

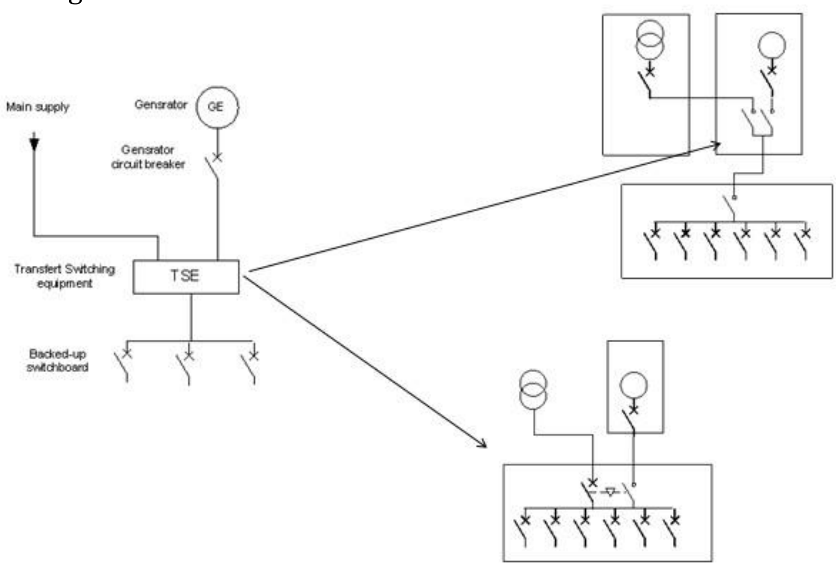

Figure 2.12: Single generator connection

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In any cases a study shall be carried out to ensure the ATS is well coordinated with the upstream protection and selectivity is achieved and the operating mode is consistent with the Utility grids

2.3.3 Circuit Simulation Using PLC Ladder Diagram

From the initial stage of circuit schematic and design, the final two type of schematic design will be run or simulate in the circuit simulation software. For this project, simulation tool used is CX-Programmer Simulation. Both circuits are tested and run with this simulation software to check and ensure the circuit is working according to the study carry out in the initial stage. Figure 2.13 shows the example of ladder diagram for this project.

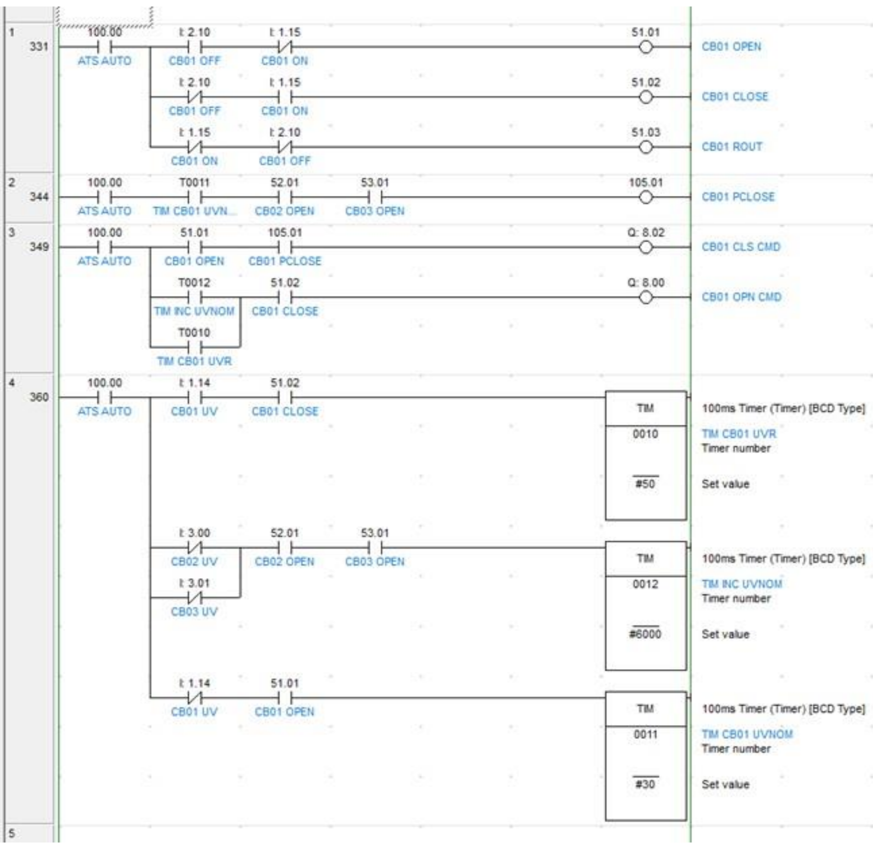

Figure 2.13: Example of Formatting Method

2.4 RESULTS AND DISCUSSION

2.4.1 Overview of testing

For verification purpose illustration of the operational by logic ladder diagram should achieve the following requirements;

- When the voltage incoming TNB1 and TNB2 drop to minimal values, Under Voltage Relay will initiate signal to the input I3.00 and I3.01 accordingly. After 3.0 second the cranking signal will send to start all Local Generator.at the same time.
- 10.0 second permission time to give for generator generates the stable voltage outgoing.
- When voltage relay Incoming Generator sensing the emergence stable voltage, after 3.0 second the command close incoming generator released to close the circuit breaker and give back the supply

2.4.2 Hardware Testing and Troubleshooting

After all the component completely assembles and the wiring check is done, testing the functionality of the input and output of the PLC configuration is made. Each of input and output from the output PLC terminal reconfirmed and supposed to meet the design drawing. If the output from the output terminal is wrong, the possibility of the output number at the CX-programmer ladder diagram is wrong number and required to be change accordingly.

For this testing and troubleshooting part, the focus is on the sequent operation CB. The output from output signal should meet the program configuration. The other focus is on hardware integration during the assembly stage. All the wiring should be properly connected to avoid the loose of the connection between the component will cause a breakdown of the total circuit. The output from the terminal output is measured to confirm the output of the component as per circuit diagram. The safety aspect is taken as a priority in this whole process.

2.4.3 Hardware Final Testing and Verification

In this stage, electronic devices or peripherals are connected to this power supply to ensure the DC output of the power supply can power up or charge the devices. Multiple types of electronic devices with voltage

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consumption 12Vdc and 24Vdc are connected to the power supply in concurrent mode to simulate of full load situation. If there is no issues or problem during this stage, the power supply is ready and safe to be used.

2.4.4 Commissioning

Project commissioning is the method to ensure all the frameworks and system are designed, installed, tested, operated, and maintained according to the operational requirements and project objectives. The commissioning process is applied not as it were to modern ventures but moreover to existing units and system subject to development, redesign, or revamping. For this project, the Isolated DC Power Supply is ready to be commercialized after all the Project Plan is to meet the target and timeline without any pending issues occur during the implementation. Figure 2.14 shows the HMI for the CB equipment status in Normal condition before any interruption.

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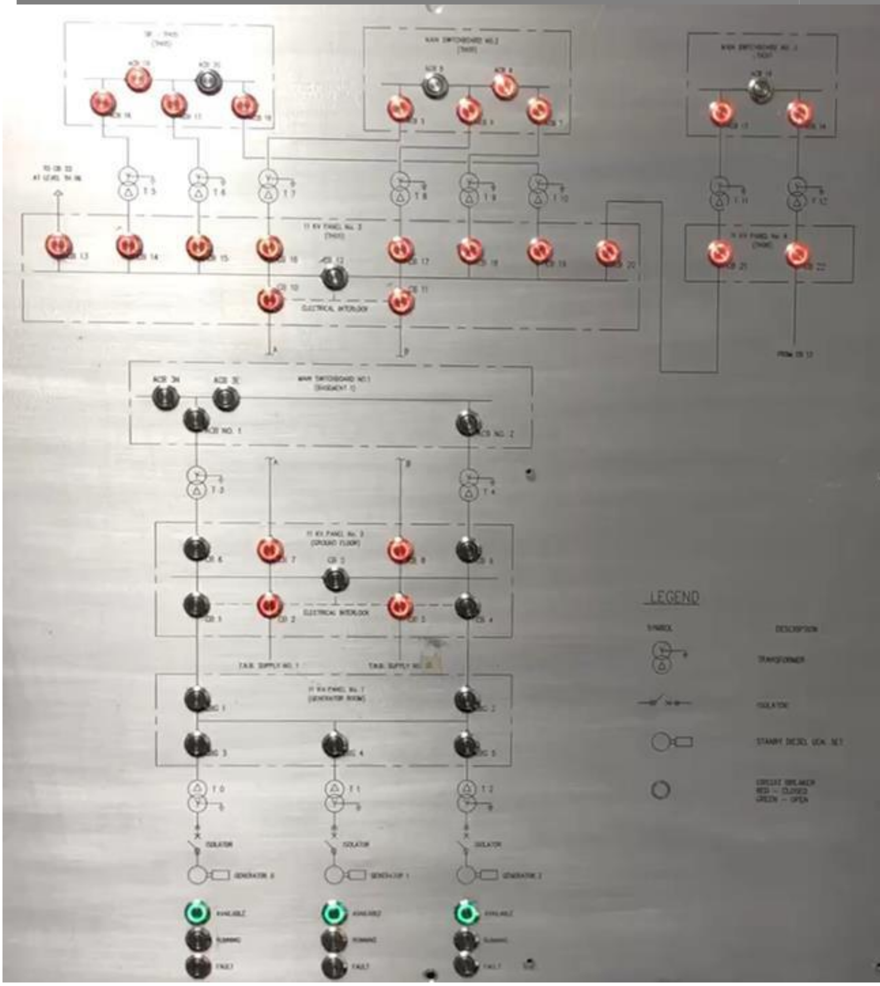

Figure 2.14: Normal Condition before any interruption

Scenario 1 – Incoming TNB2 fail

Digital Input I3.01 is setting for Under Voltage Operated Incoming TNB2. When the input simulates by Force ON, the incoming TNB2 (CB03) will trip and after 2.0sec Bus Tie (CB05) will close automatically follow by outgoing feeder (CB07) after a moment. Power Supply for the important place will normalise when the distribute CB011 close safely. The simulation of scenario 1 is defined by the following Figure 2.15.

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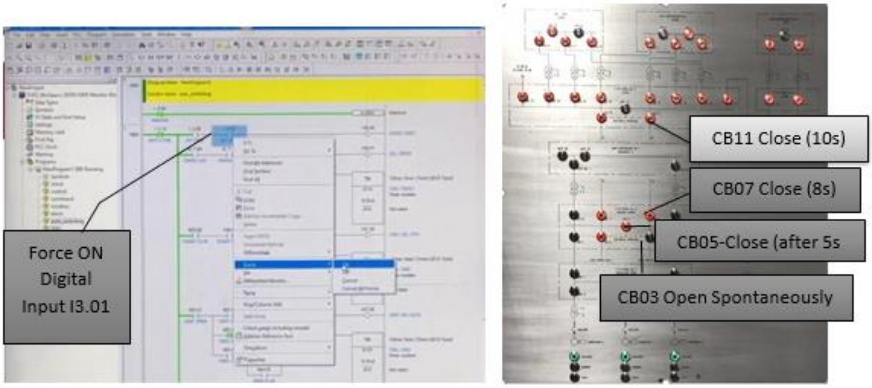

Figure 2.15: Simulation of Scenario 1

Scenario 2 – Both Incoming TNB1 and TNB2 fault

Force ON for both digital input I3.00 and I3.01 (Incoming TNB1 & TNB2). The sequent of operations are as follows:

- Both incoming TNB1 & TNB2 (CB02 & CB03) open instantly
- All available Generator Machine will be received cranking signal spontaneously and start generating backup supply
- When the generator supply stable, available Genset CB will be close one by one (CBG3, CBG4, CBG5)
- After all available Genset CB closed in 3.0 second CBG1 and follow by CBG2 sequent.
- 3 second later, CB01 and CB04 will close one after another.
- CB07 and CB08 will close after 6 second
- The supply will complete full distribute to important place after 10 second when both CB10 and CB11 closed sequent

The simulation of a scenario 2 is defined by the following Figure 2.16.

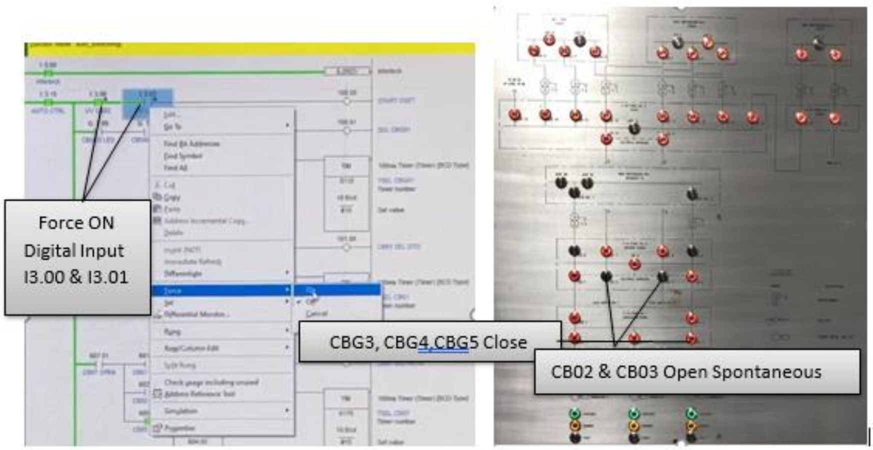

Figure 2.16: Simulation of Scenario 2

Scenario 3 – Incoming TNB Supply is normalized

When both Incoming Supply TNB1 & TNB2 normalized, by simulate on Force Clear all Force and both the digital contacts normalise (Normally Open). Operation shown in Figure 2.17 by the following sequences:

- Both incoming supply from Genset will shut down spontaneously (CB01 & CB04 Open).
- After 5 second Incoming TNB1 & TNB2 sequent close by priority, where the CB02 closure comes first and follow by CB03.
- CB07 and CB08 will close after its delay 3 second after CB02 and CB03 accordingly.
- Supply will normalise when both VB10 and CB11 close in 3 second whenever voltage sensing at their feeder.

The simulation of a scenario 3 is defined by the following Figure 2.17:

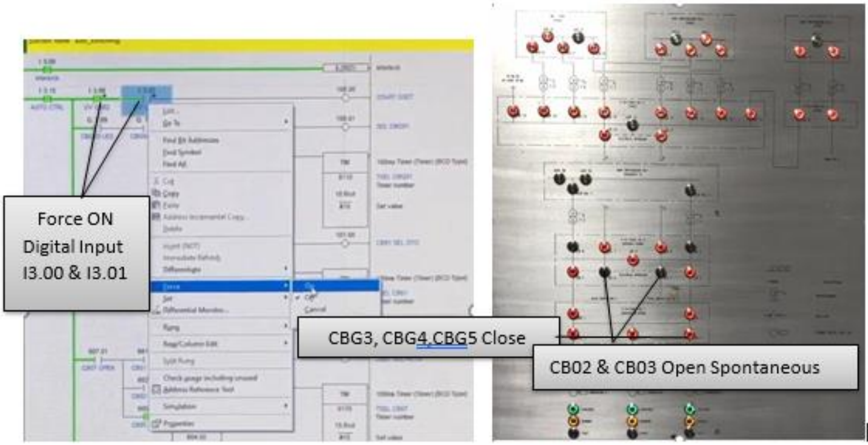

Figure 2.17: Simulation of Scenario 3

2.5 CONCLUSION

From the obtained results, the objective of the work is met. ATS is today the most efficient solution in LV and MV to secure the electrical power delivery in any industrial and building site. The correct understanding of the ATS construction and performance requirements, in addition to application of the proper standards will ensure that critical systems and equipment are supplied with efficient electrical power at any time. The overall objective of the project to design controller ATS using CX-Programmer simulation software, to construct the hardware using single line diagram via HMI with to minimize fail auto operation produced by the circuit is archived based on simulation result and hardware result.

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