Griffith School of Engineering

Project 3

Power distribution SCADA System

Equipment:

- Hardware
- RemoteConnect Software
- ClearSCADA (ViewX)

Aim:

The aim of this project is to understand the importance of using SCADA systems for Power distribution systems. This can be realized by building logic and mimic for power distribution system which supplies power for local substations and consumers in a city.

INTRODUCTION:

Objective of the project:

SCADA system is used to monitor and control the operations of large electrical networks safely and reliably. The system collects and processes the data received from other substations providing the operator with a comprehensive view of the whole network. As a result, there is no need for manual data collection and the power monitoring experts are able to detect and solve the problem quickly in their system. This project shows SCADA monitored electrical network providing electricity from substations to many consumers.

An electrical power station unit consists of a Central Power Station which supplies high-voltage electricity through distribution lines to many substations. A substation has the primary purpose of high voltage ‘step-down’ to provide electricity to all the consumers through transmission lines.

Scenarios:

This project contains 2 scenarios for power distribution in the power industry. The first scenario (Step 1) provides a Central Power Station and two substations which are connected to each other by power lines. Central Power Station is the main power source that generates large amount of energy and distributes it to substations in the power grid. Power lines transfer power from the Central Power Station to substations and substations supply power for the consumers which can be industrial and commercial customers. The purpose of the first scenario is to be familiar with small power distribution topology to implement a larger one in the second scenario. In the second scenario (Step2 - Final Step), there is a Central Power Station alongside three substations connected in a ring topology. Both scenarios contain normal operating condition and fault conditions.

First scenario:

Step 1: The Primary step with a Central Power Station and two substations

Aim:

The purpose of the first step is to be familiar with the functionality of the small power distribution topology. In this step, it is assumed that Central Power Station always supply power for substations and there is no need to initialize any input for that.

Description:

Step1 contains normal case and fault cases. In the normal case, the power is distributed without any fault, while in fault cases there is at least one fault in the power lines.

A. Normal case:

Figure 2 shows the normal case for power distribution topology in the first scenario (Step 1). The details are mentioned below:

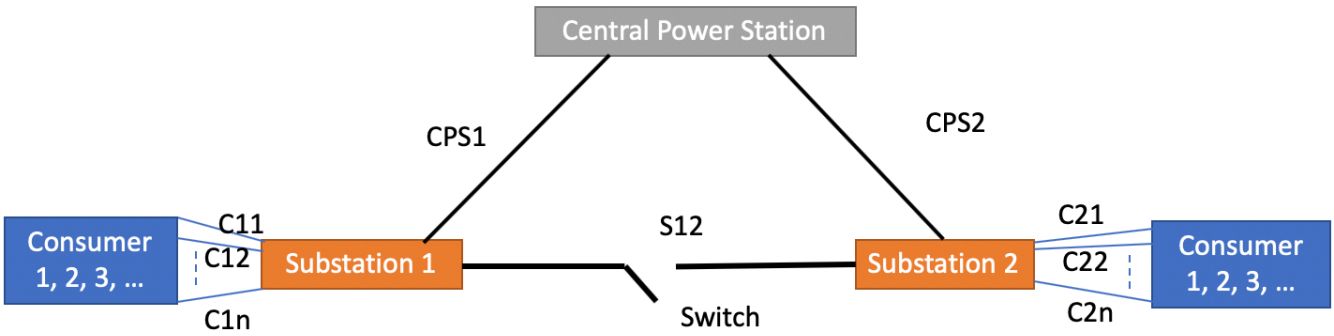

Figure 1: First scenario - Normal Case - A power distribution Scenario for SCADA System

- **Central Power Station:** This is the main power station which supplies power to other substations (Substation 1 and Substation 2).

- **Substations:** The substation is an integral part of an electrical power distribution system which transforms voltage from high to low and supplies power for consumers. Each substation supplies power to 'n' consumers.

- **Power lines:** The connections between the Central power station and Substations are represented by CPS1 and CPS2.

B. Fault Cases:

There is a need for rerouting line in fault cases to ensure that the substations receive power even in fault cases.

- **Rerouting power lines:** In this step, S12 is allocated as a switch to be connected in fault cases. It is assumed that S12 is always off (the switch is open) and will be connected in situations where there is a fault in CPS1 or CPS2. As a result, the consumers which are connected to substations receive enough power even in fault cases. For example, if there is a fault in CPS2 then S12 will be connected and the consumers of substation 2 will receive power from the central to substation 1 to substation 2 (CPS1 to S12). Figure 3 shows the example explained above.

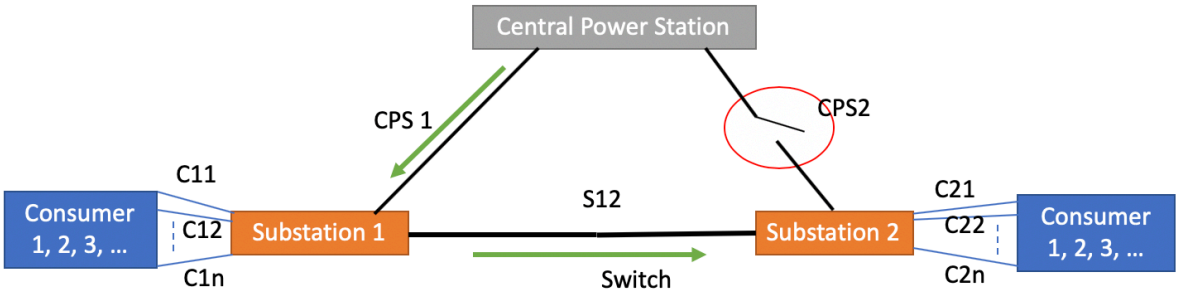

Figure 2: First Scenario- Example of fault case in CPS2

- **Fault switches:** Fault switches which are named as F1 and F2 in Figure 4 are used for two reasons:

1. To ensure that CPS1 and CPS2 are functionally active and supplying power for substations.
2. It is important to ensure that switch S12 is not closed (ON or Binary 1) when CPS1 and CPS2 are working properly. As a result, F1 and F2 would represent the fault status of CPS1 and CPS2. In short, the statuses of F1 and F2 are opposite of the statuses of CPS1 and CPS2 respectively. F1 and F2 would act as notification LEDs on the board representing the fault cases at CPS1 and CPS2.

Figure 4 shows the completed picture of step1 that must be implemented for the project.

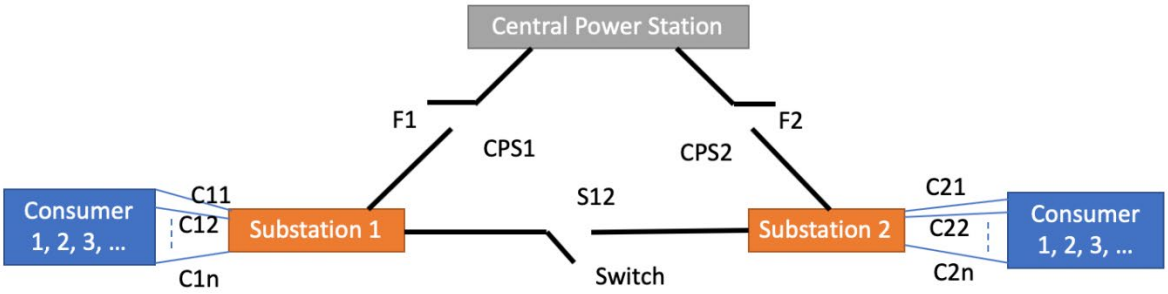

Figure 3: First scenario - Step1

Digital Inputs:

I. Input switch for CPS1 (CPS_CPS1_DI1)
II. Input switch for CPS2 (CPS_CPS2_DI2)

Digital Outputs:

I. Output status of Substation 1 (CPS_Sub1_DO1)
II. Output status of Substation 2 (CPS_Sub2_DO2)
III. Output switch for the fault at CPS1 (F1) (CPS_F1_DO3)
IV. Output switch for the fault at CPS2 (F2) (CPS_F2_DO4)
V. Output status of S12 (CPS_S12_DO5)

Truth table:

Table 1 indicates the truth table for step 1 logic. Fill the table and try to figure out the logic.

Table 1: Truth table for Step 1

Inputs		Outputs				
CPS1	**CPS2**	**F1**	**F2**	**S12**	**Sub1**	**Sub2**
0	0					
0	1					
1	0					
1	1					

Note 1: Implement the logic in RemoteConnect and ClearSCADA (ViewX) software.

Note 2: The project can be implemented in any of the three languages (Functional Block Diagram, Structural Text or Ladder).

Second scenario:

The second scenario contains five steps considering three situations:

1. Normal Case **(Step 2)**
2. Fault situation on one line and power re-routing **(Step 3)**
3. Fault situation on two lines and power re-routing **(Step 4 and Step5)**
4. All the possibilities that occur in a three substations system with four digital inputs **(Final Step)**

Step 2: Adding the third substation to the existing power topology

This step comprises of three substations connected to a central power station. The topology in which the Central Power Station is connected to the three substations is a ring structure. Each substation has ‘n’ consumers connected to it.

In this step, a third substation (Substation3) is added to the power distribution system. Power is distributed to substation 1 and substation 2 from Central Power Station. Then Substation 1 and Substation 2 provide power to Substation3, through power lines named S13 and S23.

In this step, it is assumed that there is no fault in any of the power lines which means all the substations receive adequate power. Therefore, it is considered as a “NORMAL” operating case.

Figure 5 shows a scenario of step2 for power distribution in this project.

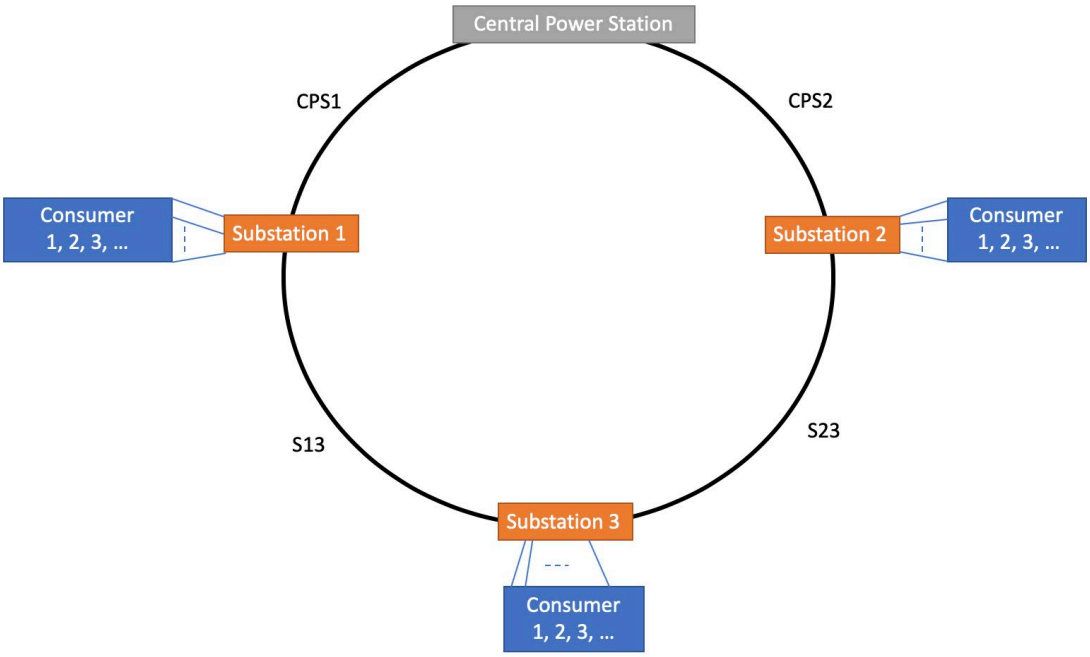

Figure 4: Second scenario- Normal working case.

Digital Inputs and Outputs:

Digital Inputs:

I. Input switch for CPS1 (CPS_CPS1_DI1)
II. Input switch for CPS2 (CPS_CPS2_DI2)
III. Input switch for S13 (CPS_S13_DI3)
IV. Input switch for S23 (CPS_S23_DI4)

Digital Outputs:

I. Output status of Substation 1 (CPS_Sub1_DO1)
II. Output status of Substation 2 (CPS_Sub2_DO2)
III. Output status of Substation 3 (CPS_Sub3_DO6)

Truth table:

Table 2 indicates the truth table for step 2 logic. Fill the table and try to figure out the logic.

Table 2: Truth Table for Step 2

Inputs				Outputs		
CPS1	**CPS2**	**S13**	**S23**	**Sub1**	**Sub2**	**Sub3**
1	1	1	1			

Note 1: Implement the logic in RemoteConnect and ClearSCADA (ViewX) software.

Note 2: The project can be implemented in any of the three languages (Functional Block Diagram, Structural Text or Ladder).

Step 3: Fault situation on one line and power re-routing

This step is focused on one fault which can occur in any of the power lines. The fault can be on CPS1, CPS2, S13 or S23. If there is a fault in any of these power lines, then the respective substation will not receive power and it turns off (Binary 0). As a result, there is a need for two extra rerouting power lines (S12 and CPS3) which work as a switch and will be connected only in a fault case, which is represented in Figure 6.

The power Lines are able to provide one third, two third or the whole required power for substations whenever it is required. It is assumed that the amount of power in each power lines is controlled by the power monitoring experts and this project does not cover power measurements for power lines.

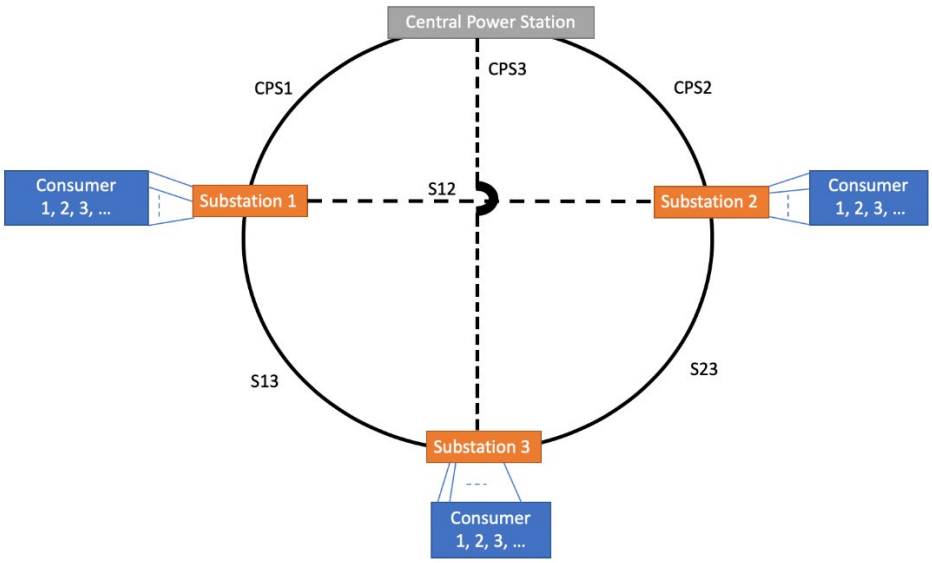

Figure 5: Addition of CPS3 and S12 to the existing topology

- If there is a fault in CPS1 or CPS2, then power line switch for S12 must be turned ON (Binary 1). So, all the substations would receive power even when there is a fault (Figure 7).

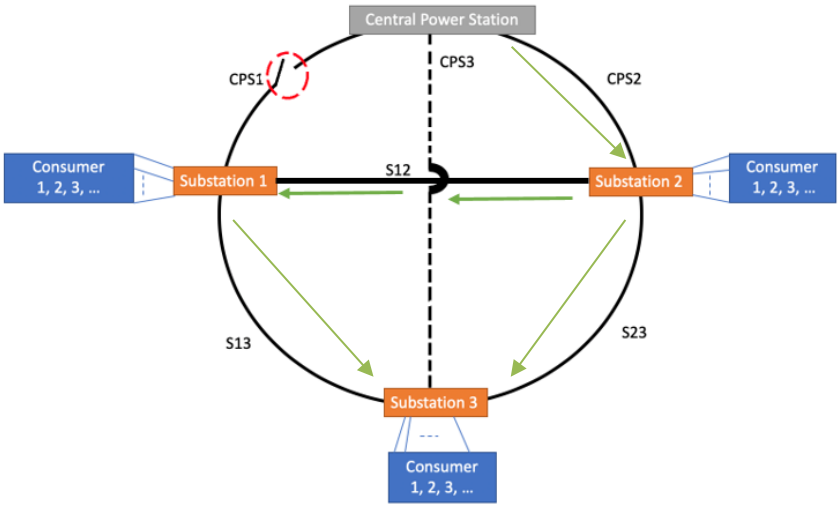

Figure 6: Fault situation at CPS1 and power re-routing.

- If there is a fault in S13 or S23, then the power line switch for CPS3 must be turned ON. This ensures that Sub3 would receive power even when there is a fault (Figure 8).

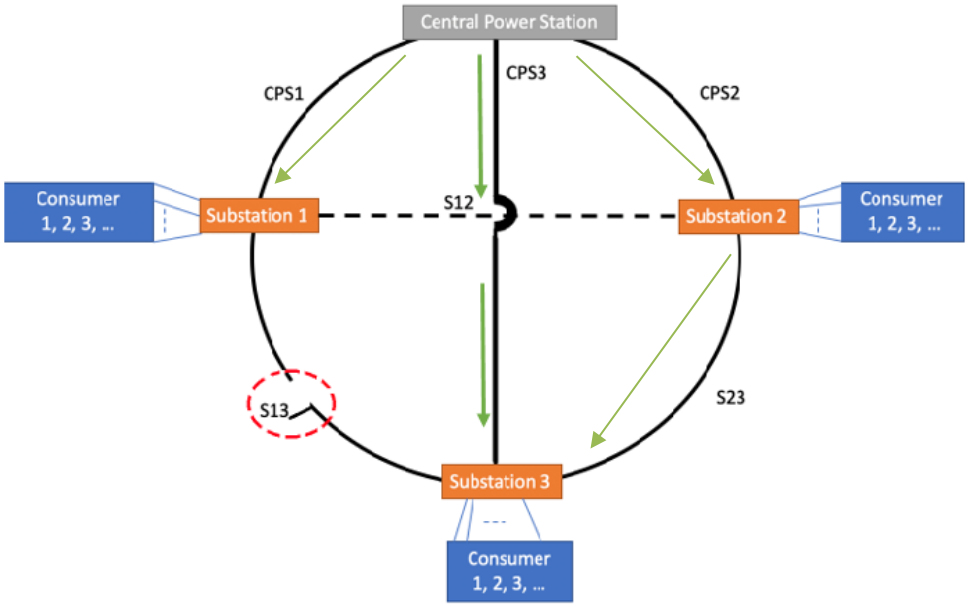

Figure 7: Fault situation at S13 and power re-routing

Digital Inputs and Outputs:

Digital Inputs:

I. Input switch for CPS1 (CPS_CPS1_DI1)
II. Input switch for CPS2 (CPS_CPS2_DI2)
III. Input switch for S13 (CPS_S13_DI3)
IV. Input switch for S23 (CPS_S23_DI4)

Digital Outputs:

I. Output status of Substation 1 (CPS_Sub1_DO1)
II. Output status of Substation 2 (CPS_Sub2_DO2)
III. Output status of Substation 3 (CPS_Sub3_DO6)
IV. Output status of Power line S12 (CPS_S12_DO5)
V. Output status of Power line CPS3 (CPS_CPS3_DO7)

Truth table:

Table 3 indicates the truth table for step 3 logic. Fill the table and try to figure out the logic.

Table 3: Truth table for Step 3

Inputs				Outputs				
CPS1	**CPS2**	**S13**	**S23**	**Sub1**	**Sub2**	**Sub3**	**S12**	**CPS3**
0	1	1	1	**1**	**1**	**1**	**1**	**0**
1	0	1	1	**1**	**1**	**1**	**1**	**0**
1	1	0	1	**1**	**1**	**1**	**0**	**1**
1	1	1	0	**1**	**1**	**1**	**0**	**1**

Note 1: Implement the logic in RemoteConnect and ClearSCADA (ViewX) software.

Note 2: The project can be implemented in any of the three languages (Functional Block Diagram, Structural Text or Ladder).

Fault situation on two lines and power rerouting for both lines

Step 4: The fault in CPS1 and CPS2 or S13 and S23

This step is focused on two faults which can occur in either CPS1 and CPS2 or S13 and S23. In case of faults in the power lines (CPS1and CPS2 or S13 and S23) to the respective substations, then CPS3 should be active in both the cases.

- CPS3 is active when CPS1 and CPS2 are at faults, so the power can be re-routed through S13 and S23 to the substations, Sub1 and Sub2.
- When S13 and S23 are having faults, then also CPS3 will be active and provides power to Sub3. Here power line S12 is not used because the shortest pathway is considered. As a result, all the 3 substations namely Sub1, Sub2 and Sub 3 is getting power to feed their customers. The working is shown in Figure 9.

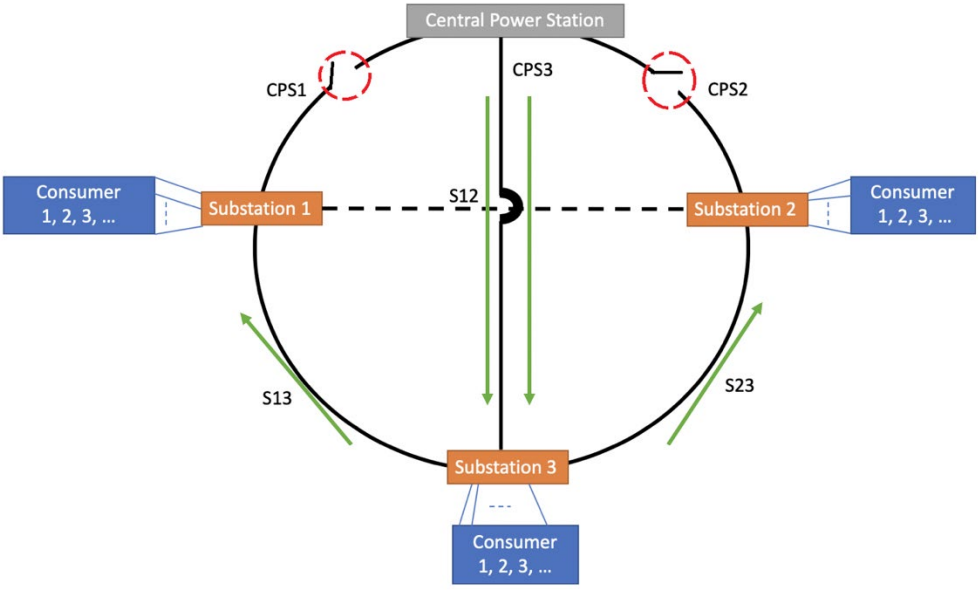

Figure 8: Step 4 – fault situation in CPS1 and CPS2 and power rerouting

Digital Inputs and Outputs:

Digital Inputs:

I. Input switch for CPS1 (CPS_CPS1_DI1)
II. Input switch for CPS2 (CPS_CPS2_DI2)
III. Input switch for S13 (CPS_S13_DI3)
IV. Input switch for S23 (CPS_S23_DI4)

Digital Outputs:

I. Output status of Substation 1 (CPS_Sub1_DO1)
II. Output status of Substation 2 (CPS_Sub2_DO2)
III. Output status of Substation 3 (CPS_Sub3_DO6)
IV. Output status of Power line S12 (If required) (CPS_S12_DO5)
V. Output status of Power line CPS3 (If required) (CPS_CPS3_DO7)

Truth table:

Table 4 indicates the truth table for step 4 logic. Fill the table and try to figure out the logic.

Table 3: Truth table for Step 4

Inputs				Outputs				
CPS1	**CPS2**	**S13**	**S23**	**Sub1**	**Sub2**	**Sub3**	**S12**	**CPS3**
0	0	1	1	**1**	**1**	**1**	**0**	**1**
1	1	0	0	**1**	**1**	**1**	**0**	**1**

Logic Implementation:

Considering faults in the inputs (CPS1 and CPS2) or (S13andS23), it must be made sure that all the 3 substations (Sub1, Sub2, Sub3) receive enough power.

Note 1: Implement the logic in RemoteConnect and ClearSCADA (ViewX) software.

Note 2: The project can be implemented in any of the three languages (Functional Block Diagram, Structural Text or Ladder).

Step5: Fault occurring in two lines simultaneously (CPS1, CPS2, S13, and S23)

In addition to Step 4, this step covers all the two fault conditions that can occur in four lines (CPS1, CPS2, S13, and S23). Three possibilities of two-fault cases are shown in Figure 9 to Figure 11.

- An attempt should be made to realize the best re-routing path and must be labeled with arrows on Figure 10 and Figure 11. After doing so, a logic for this step must also be thought out and realized to ensure all substations receive power.

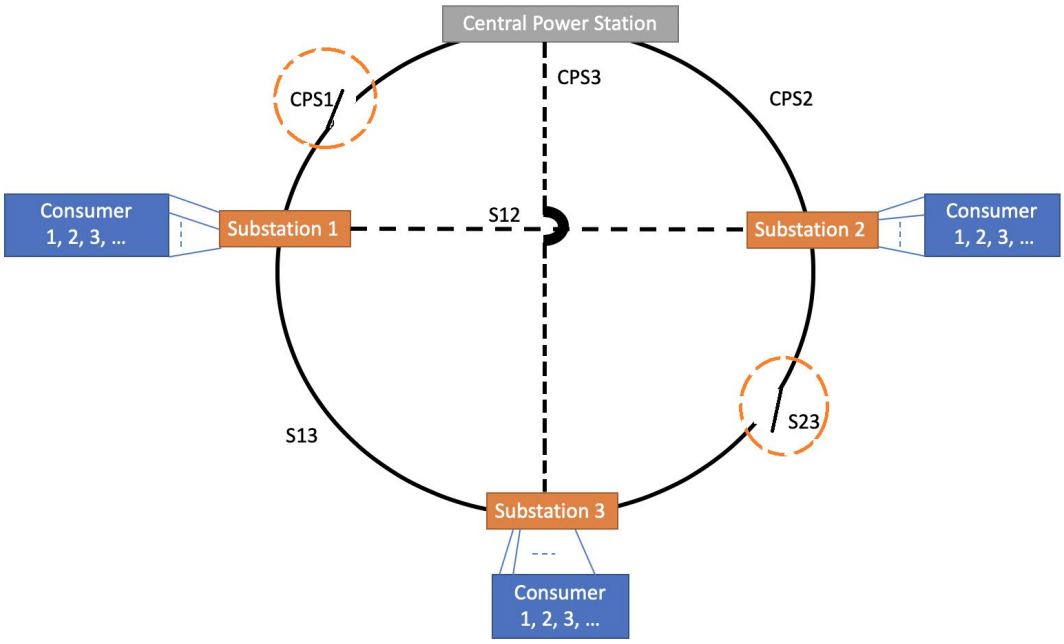

Figure 9: Fault situation in CPS1 and S23 lines and power rerouting.

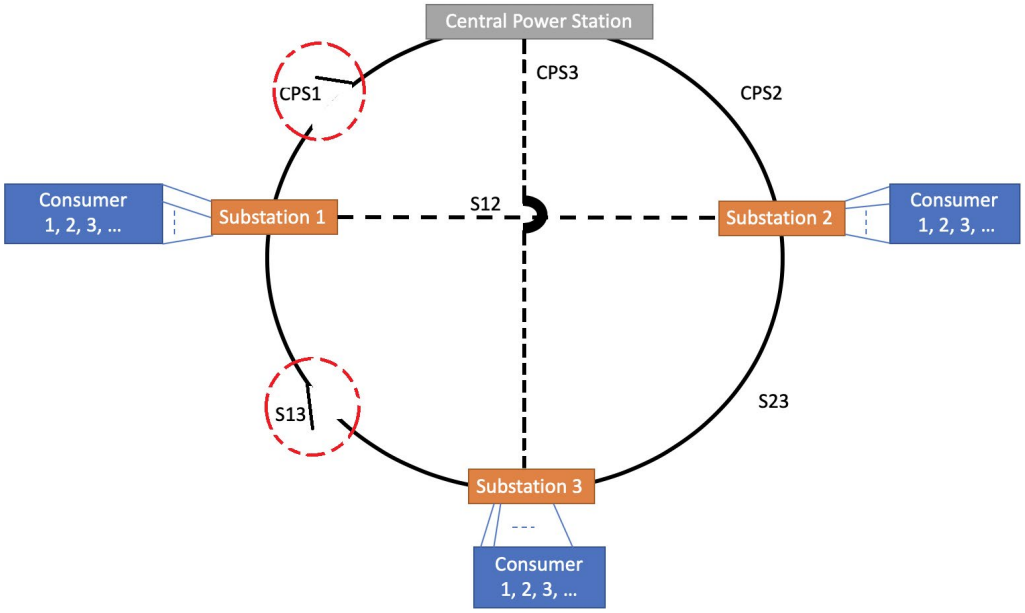

Figure 10: Fault situation in CPS1 and S13 lines and power rerouting.

Digital Inputs and Outputs:

Digital Inputs:

I. Input switch for CPS1 (CPS_CPS1_DI1)
II. Input switch for CPS2 (CPS_CPS2_DI2)
III. Input switch for S13 (CPS_S13_DI3)
IV. Input switch for S23 (CPS_S23_DI4)

Digital Outputs:

I. Output status of Substation 1 (CPS_Sub1_DO1)
II. Output status of Substation 2 (CPS_Sub2_DO2)
III. Output status of Substation 3 (CPS_Sub3_DO6)
IV. Output status of Power line S12 (If required) (CPS_S12_DO5)
V. Output status of Power line CPS3 (If required) (CPS_CPS3_DO7)

Truth table:

Table 5 indicates the truth table for step 5 logic. Fill the table and try to figure out the logic.

Table 4: Truth table for Step 5

Inputs				Outputs				
CPS1	**CPS2**	**S13**	**S23**	**Sub1**	**Sub2**	**Sub3**	**S12**	**CPS3**
0	0	1	1	**1**	**1**	**1**	**0**	**1**
1	1	0	0	**1**	**1**	**1**	**0**	**1**
0	1	0	1	**1**	**1**	**1**	**1**	**1**
1	0	0	1	**1**	**1**	**1**	**1**	**1**
0	1	1	0	**1**	**1**	**1**	**1**	**1**
1	0	1	0	**1**	**1**	**1**	**1**	**1**

Note 1: Implement the logic in RemoteConnect and ClearSCADA (ViewX) software.

Note 2: The project can be implemented in any of the three languages (Functional Block Diagram, Structural Text or Ladder).

Final Step:

This step covers all the possibilities that occur in a three substations system with four digital inputs (CPS1, CPS2, S13, and S23).

Digital Inputs and Outputs:

Digital Inputs:

V. Input switch for CPS1 (CPS_CPS1_DI1)
VI. Input switch for CPS2 (CPS_CPS2_DI2)
VII. Input switch for S13 (CPS_S13_DI3)
VIII. Input switch for S23 (CPS_S23_DI4)

Digital Outputs:

VI. Output status of Substation 1 (CPS_Sub1_DO1)
VII. Output status of Substation 2 (CPS_Sub2_DO2)
VIII. Output status of Substation 3 (CPS_Sub3_DO6)
IX. Output status of Power line S12 (If required) (CPS_S12_DO5)
X. Output status of Power line CPS3 (If required) (CPS_CPS3_DO7)

Figure 14 shows the picture of the explained scenario for Final Step.

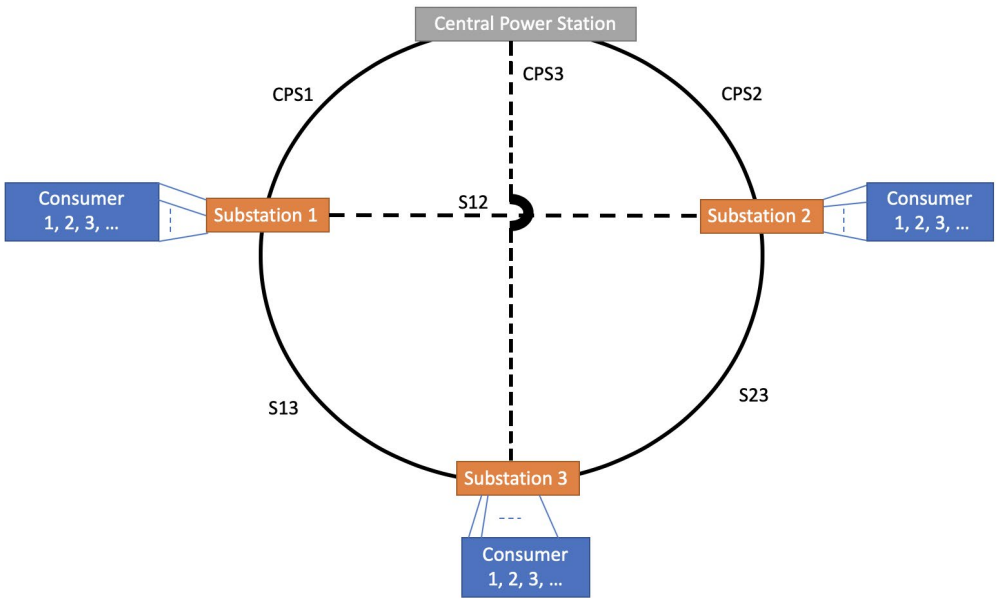

Figure 11: Power distribution system for the Final Step.

Truth table:

Table 6 indicates the truth table for the Final Step logic. Fill the table and try to figure out the logic.

Table 5: Truth table for the Final Step

Inputs				Outputs				
CPS1	**CPS2**	**S13**	**S23**	**Sub1**	**Sub2**	**Sub3**	**S12**	**CPS3**
0	0	0	0	**0**	**0**	**1**	**0**	**1**
0	0	0	1	**1**	**1**	**1**	**1**	**1**
0	0	1	0	**1**	**1**	**1**	**1**	**1**
0	0	1	1	**1**	**1**	**1**	**0**	**1**
0	1	0	0	**1**	**1**	**1**	**1**	**1**
0	1	0	1	**1**	**1**	**1**	**1**	**1**
0	1	1	0	**1**	**1**	**1**	**1**	**1**
0	1	1	1	**1**	**1**	**1**	**1**	**0**
1	0	0	0	**1**	**1**	**1**	**1**	**1**
1	0	0	1	**1**	**1**	**1**	**1**	**1**
1	0	1	0	**1**	**1**	**1**	**1**	**1**
1	0	1	1	**1**	**1**	**1**	**1**	**0**
1	1	0	0	**1**	**1**	**1**	**0**	**1**
1	1	0	1	**1**	**1**	**1**	**0**	**1**
1	1	1	0	**1**	**1**	**1**	**0**	**1**
1	1	1	1	**1**	**1**	**1**	**0**	**0**

Note 1: Implement the logic in RemoteConnect and ClearSCADA (ViewX) software.

Note 2: The project can be implemented in any of the three languages (Functional Block Diagram, Structural Text or Ladder).

Note 3: Fault cases are not considered for CPS3 and S12 in all the steps.