



Micro Grid Automation with Unique Features of Power Flow Control by using SCADA

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Abstract— Now a days, the load demand of the world is dramatically increasing day by day. This situation creates a big gap between the energy production and the energy consumption. The conventional energy sources are depleting globally. So it is a global phenomenon to restore the power energy and to look forward the other means of energy production. The load demand and power production gap can be reduced by Micro Grid. Micro grids is a group of localized electricity units and load that operates both in islanded mode/ autonomously or in grid connected mode. Grid connected mode is a small power generating unit that is connected with conventional grid system. Grid connected mode is a small power generating unit that is being connected with conventional grid system. Micro grid mostly utilizes the renewable sources of energy such as solar energy, wind energy, geo thermal energy and the other sources of distributed generation. While operating a power system in micro grid, the maintenance and flow of electricity is not simple task as compared to the unidirectional power flow in case of conventional grid station. Another problem is the identification of fault in power system in case of micro grids detection of fault location and its recovery is not an easy task. In this research work, I have developed a SCADA module through which fault location is detected automatically, by observing the power at different feeders and its dial recovery is done by supply the power from other nearby power generating station. This is only possible when the system has ability to operate in ring main system, but it normally operates in radial configuration.

Keywords— Smart Grid, Micro Grid, Power System, Power Transmission, SCADA, PLC.

I. INTRODUCTION

Micro grid is a group of localized electricity units and load that either operates in islanded mode/autonomously or in grid connected mode (small power generation unit connected with conventional grid system) [1].

When micro grid operates in islanded mode it works like an isolated system. It reduces transmission cost, because no transmission line is required. There should be only generating units and distribution system for it [2].

Reliability of system is main issue for both consumers and the power producers. In case of occurrence of fault in distribution line, whole system or in a part of system power becomes disconnected, which further produce black out condition at some feeders. In order to compensate the fault usually the system is operated with radial configuration but when fault occurs at any point of circuit, the configuration of system would be changed to ring main in order to restore the system with minimum possible load disconnected [2][3].

In this research project, algorithm has been developed in order to automatically change the system configuration in case of fault and detection of fault location. The hardware that should be used for this purpose was programmable logic controller and smart meters. The PLC collect reading from smart meters and then decision has to make about logical and mathematical operation of system configuration according to the developed algorithm.

II. MICRO GRID AUTOMATION WITH POWER FLOW CONTROL BY USING SCADA

In case of conventional grid station power flow usually occurs from generating station to load center. But in case of micro grid station power flow occurs in both directions and its power flow control is also not an easy task. In this research work a SCADA system is introduced, through which the fault location will be automatically detected by monitoring power at different feeders. The second problem that is also solved by using same scenario is the recovery of fault, which is only possible if nearby generating station has spare power to feed that feeder. The whole scheme is implemented by considering that the system has ability to operate in ring main system, but normally operates in radial configuration.

A. Automation with PLC & SCADA Softwares

Programmable logic Controller (PLC) is controlling unit. The fault detection and decision how and when system configuration change will be decided by PLC.

- Two software's are used in order to operate them. "WinLog Lite" software is used to operate SCADA system and "GX.

Developer" is used for programing of Programmable Logic Controller.

Winlog Lite is very convenient for utilization, more reliable and easier to use software package in formation of the SCADA/ HMI techniques along with the supportive nature of Web Server.

GX Developer and simulator is software use to develop program for Programmable logic controller (PLC). The whole logic operation is programed in GX Developer. This Software is usually utilized as a single program debugging element using the PLC for debugging in advance and conventional way required not just the Programmable Logic Controller but also I/O and special modules and external use devices.

B. Inter Connection Scheme

In this research, a new idea has been proposed, in which the system is operated in islanded mode but in condition of fault at generator side or in condition of line fault, the system has ability to convert from islanded mode to ring main system.

The whole scenario can be described with the help of figure 1.1.

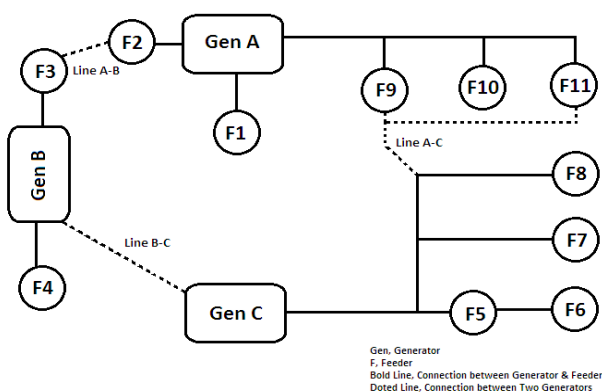


Figure 1.1: Ring main system

The above mentioned system is ring main distribution system. There are total 11 feeders as shown in the system, which is supplied by three different power sources. Initially the system is worked as radial system with lines A-B, A-C and B-C are not energized.

In the case of fault at any generator, the system configuration will change from radial to ring main and power supply will be provided by nearby generator. It can only be possible if the nearby generator has spare power and concern transmission line has capacity to transmit power.

The change of system configuration from radial to ring main is controlled and monitored by SCADA and PLC system.

The PLC (Programmable Logic Controller) takes all the decisions, regarding fault detection, change of system configuration and restoration of system. On the other hand, the SCADA (Supervisory Control and Data Acquisition) provides human machine interface. SCADA provides visual display of whole scenario.

C. Condition of Lines at different conditions of Generators

At different condition of generators (either they are normal or in faulted condition) the line would be energized or not depending upon particular situation. The isolator and circuit breaker are installed at both ends of all lines connected to all generators and feeders. With the help of PLC that circuit breakers would be ON/OFF, which further maintain the condition of line (energized/ de-energized). The figure 1.2 shows the whole scenario of system with three generators and eleven feeders.

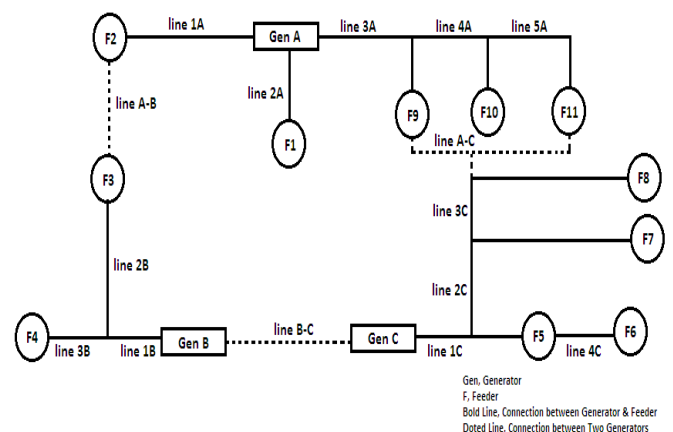


Figure 1.2 Power System with three Generators & Eleven Feeders.

In normal case, all generators are in operating condition, so all lines are energized except that lines which connect two generators (line 'A-B', 'A-C' & 'B-C'), because in this condition system work in radial fashion shown in figure 4.1.

In second case fault occur at generator 'C'. In this condition all lines remain energized except line '2C', line '4C' and line 'A-B', which become de-energized. The

The all cases are summarized into a table form and given below, where '1' represent energized state and '0' represent off/ de-energized state.

Table 1.1 (a) Condition of Lines at different conditions of Generators

S r #	Ge n A Y1 00	Ge n B Y2 00	Ge n C Y3 00	Lin e 1A Y1 01	Lin e 2A Y1 02	Lin e 3A Y1 03	Lin e 4A Y1 04	Lin e 5A Y1 05	Lin e 1B Y2 01	Lin e 2B Y2 02	Lin e 3B Y2 03
1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	0	1	1	1	1	1	1	1	1
3	1	0	1	1	1	1	1	1	0	1	1
4	1	0	0	1	1	1	1	1	0	1	1
5	0	1	1	1	1	0	0	0	1	1	1
6	0	1	0	1	1	0	0	0	1	1	1
7	0	0	1	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0

Table 1.1 (b) Condition of Lines at different Conditions of Generators

Sr #	Gen A Y100	Gen B Y200	Gen C Y300	Line 1C Y301	Line 2C Y302	Line 3C Y303	Line 4C Y304	Line A-B Y401	Line A-C Y402	Line B-C Y403
1	1	1	1	1	1	1	1	0	0	0
2	1	1	0	1	0	1	0	0	1	1
3	1	0	1	1	1	1	1	1	0	0
4	1	0	0	0	0	1	0	1	1	0
5	0	1	1	1	1	1	1	1	1	0
6	0	1	0	1	0	0	0	1	0	1
7	0	0	1	1	1	1	1	0	1	0

D. Condition of feeders at different condition of Generators

At different condition of generators (either they are normal or in faulted condition) the line would be energized or not depending upon particular situation, which further decide whether a particular feeder should be loaded or not. The different conditions of feeder at different condition of generator is given below. The whole scenario can be understand with the help of figure 4.1.

In first case there is no fault occur at any generator. In this condition all feeders remain in normal/ operating condition.

In second case fault occur at generator 'C', which results in shut down at feeder 6, while all other feeders remain in its normal state. Feeder 5 of generator 'C' will be supplied by generator 'B' through line 'B-C' and feeder 7, 8 of generator 'C' is supplied by generator 'A' through line 'A-C'.

The all other cases at different condition of fault is summarized in tabular form and given below, where '1' represent energized state and '0' represent off/ de-energized state. The feeder & generator are represented by 'F' & 'Gen' respectively.

Table 1.2 (a) Condition of Feeders at different conditions of Generators

Sr #	Gen A Y100	Gen B Y200	Gen C Y300	F 1 Y1	F 2 Y2	F 3 Y3	F 4 Y4	F 5 Y5	F 6 Y6
1	1	1	1	1	1	1	1	1	1
2	1	1	0	1	1	1	1	1	0
3	1	0	1	1	1	1	1	1	1
4	1	0	0	1	1	1	1	0	0
5	0	1	1	1	1	1	1	1	1
6	0	1	0	1	1	1	1	1	0
7	0	0	1	0	0	0	0	1	1

Table 1.2 (b) Condition of Feeders at different conditions of Generators

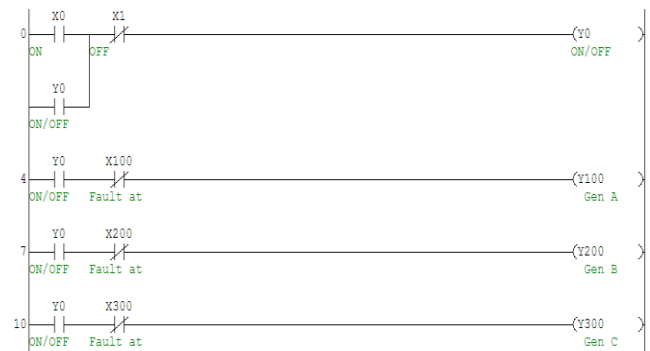
Sr #	Gen A Y100	Gen B Y200	Gen C Y300	F 7 Y7	F 8 Y8	F 9 Y9	F 10 Y10	F 11 Y11
1	1	1	1	1	1	1	1	1
2	1	1	0	1	1	1	1	1
3	1	0	1	1	1	1	1	1
4	1	0	0	1	1	1	1	1
5	0	1	1	1	1	1	0	1
6	0	1	0	0	0	0	0	0
7	0	0	1	1	1	1	0	1

E. PLC Program (Develop on GX Developer)

The Programmable Logic Controller (PLC) is decision making device. The program is written in GX Developer software and then burn in PLC module.

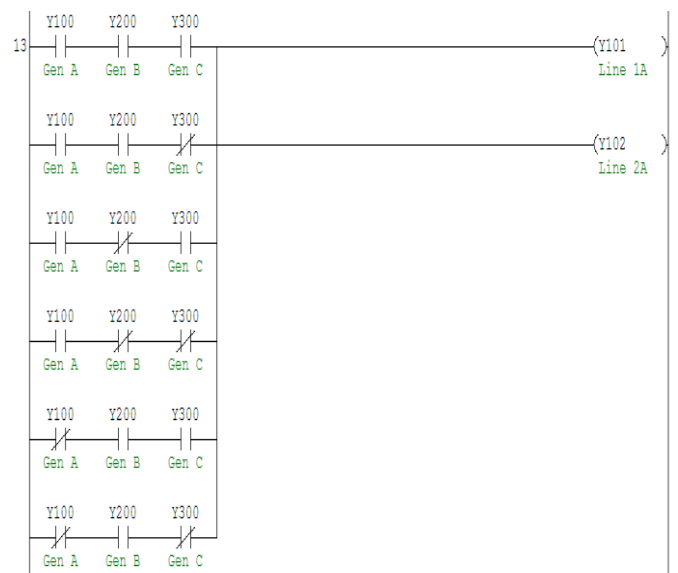
In this program Part 1 'X0' is input switch to ON the power system and 'X1' is used to shut down the whole power system. The 'Y0' coil shows the output status of system.

If system is in normal condition, then after switch on the power system the all generators should be start working. 'Y100', 'Y200' and 'Y300' represents the generator 'A', 'B' and 'C' respectively. Whereas normally closed switches 'X100', 'X200' and 'X300' represents fault at generator 'A', 'B' and 'C' respectively.



GX Developer Program Part: 1

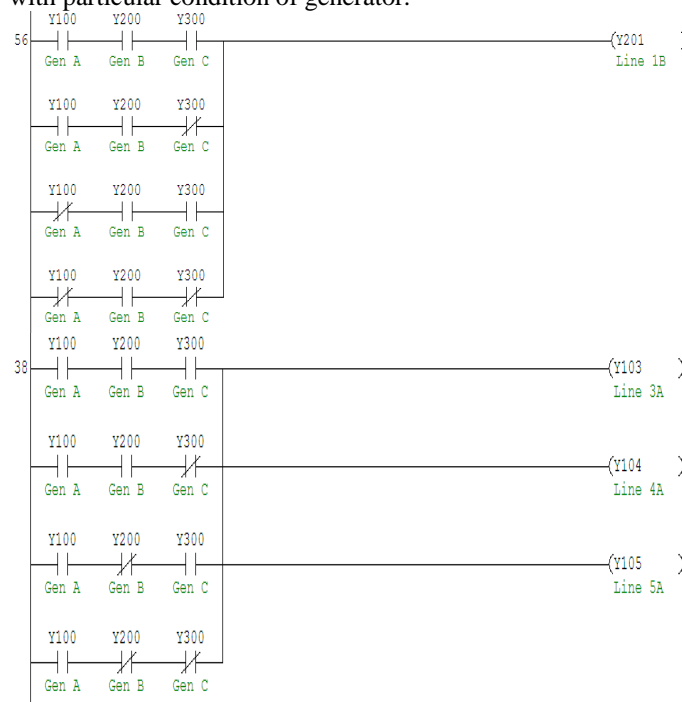
In part 2 of program the conditions of operation of lines '1A' and '2A' associated with generator 'A' is describe according to table 4.1. The program is written only for those cases, when there is '1' (ON State) at output of line, with particular condition of generator.



GX Developer Program Part: 2

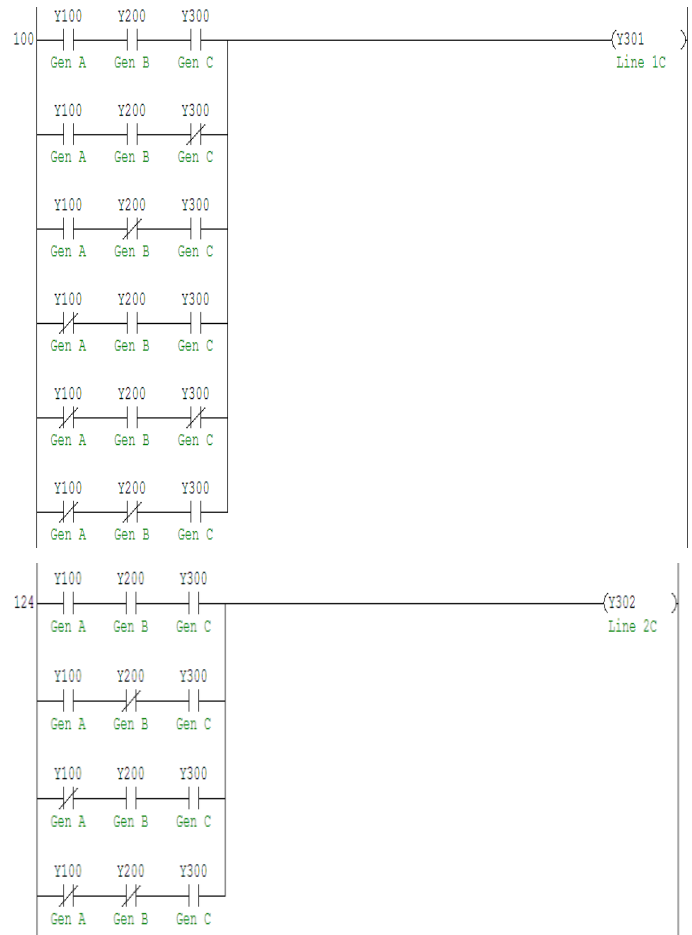
Similarly in part 3 of program the conditions of operation of lines '3A', '4A', '5A' and '1B' associated with generator 'A' and 'B' is describe according to table 4.1. The program is

written only for those cases, when there is '1' at output of line, with particular condition of generator.

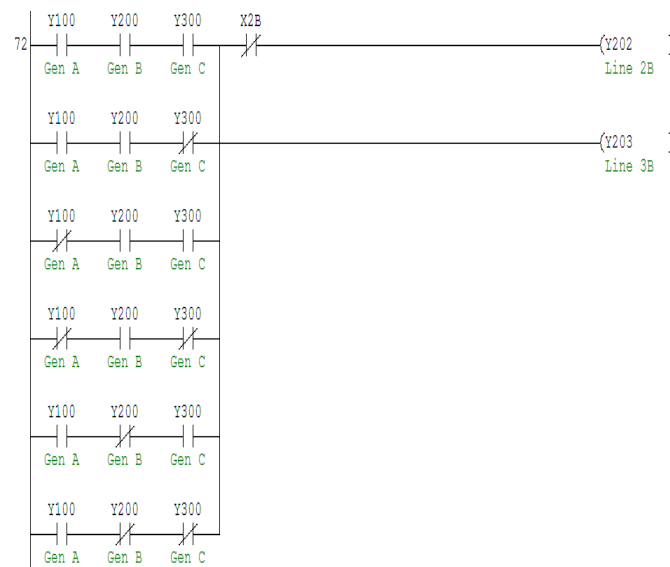


GX Developer Program Part: 3

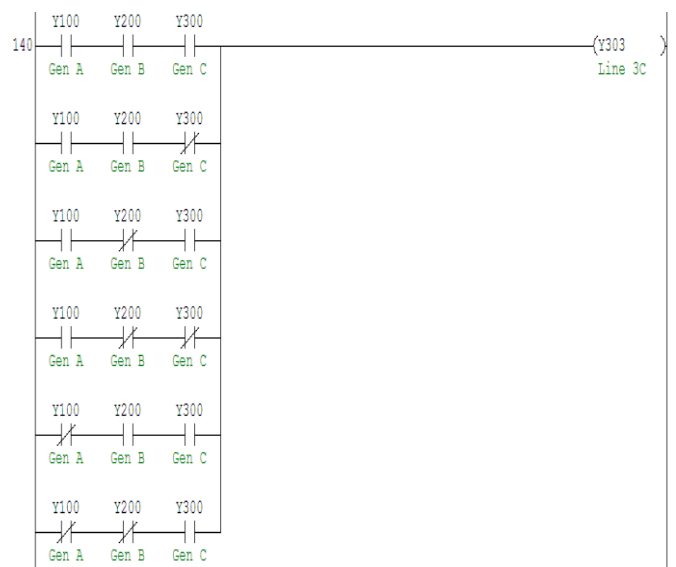
In part 4 of program the conditions of operation of lines '2B', '3B', '1C', and '2C' associated with generator 'B' and 'C' is mentioned with respect to table 4.1. The program is written only for those cases, when there is '1' at output of line, with particular condition of generator.

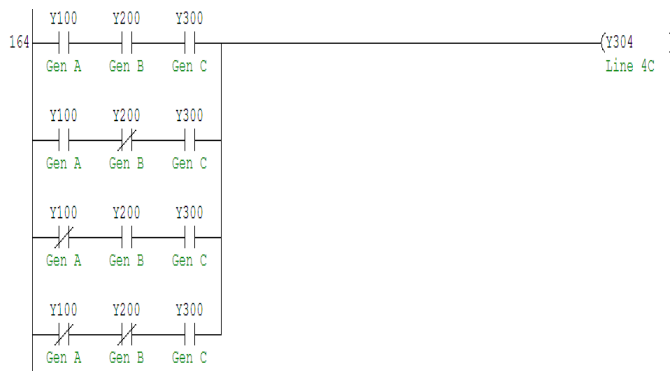


GX Developer Program Part: 4



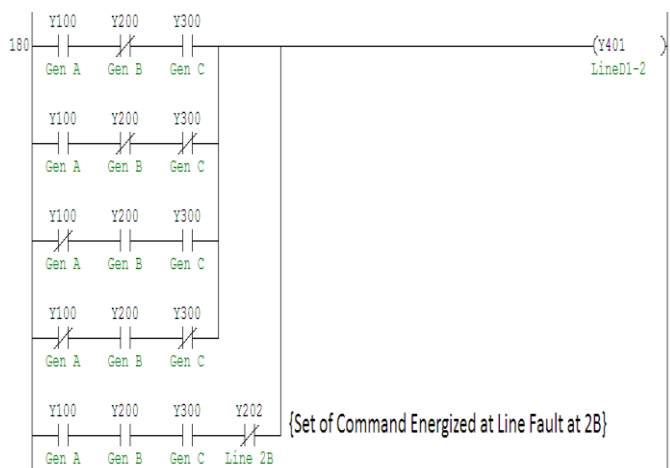
In part 5 of program the conditions of operation of lines '3C' and '4C' associated with generator 'C' is mentioned with respect to table 4.1. The program is written only for those cases, when there is '1' at output of line, with particular condition of generator.





GX Developer Program Part: 5

In part 6 of program condition of operation of line 'D1-2' is mentioned by considering table 4.1. The line 'D1-2' connects generator 'A' and generator 'B' in the condition of fault at either generator or in condition of line fault. The last line of part 6 of program only operate when a line fault at line '2B' occur.



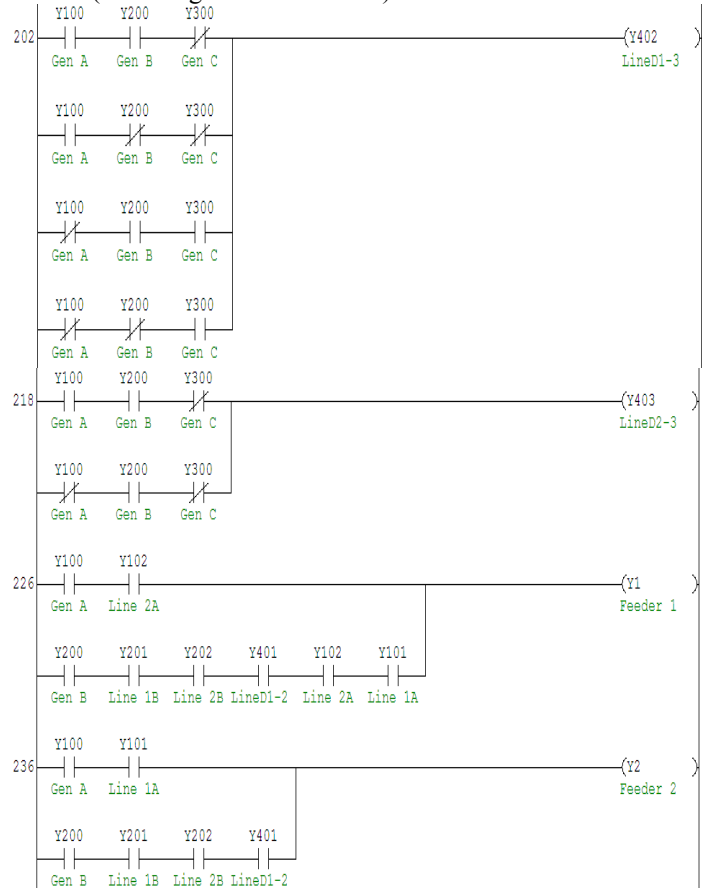
GX Developer Program Part: 6

In part seven of the program condition of operation of line 'D2-3' and line 'D2-3' is given. The line 'D2-3' connects generator 'B' and 'C' in the condition of fault and 'D2-3' connects generator 'B' and 'C' in the condition of fault. While developing the algorithm, the table 4.1 should kept in mind. The whole algorithm is according to table 4.1.

In part seven the operating status of feeder 1 and 2 is also mentioned. The operating status of feeder is not just depend upon condition of generator (table 4.2), but it is also depend upon actual configuration of system. For example the feeder 1 operate in two conditions. Feeder 1 operates when there is generator 'A' in system along with line '2A' because line '2A' connects feeder 1 with generator 'A'. The other condition of operation of feeder 1 is presence of generator 'B' along with line '1B', '2B', 'D1-2', '2A' and line '1A'.

The operating condition of feeder 2 is either presence of generator 'A' along with line '1A' and other condition is

presence of generator 'B' along with line '1B', '2B' and line 'D1-2' (connect generator A and B).

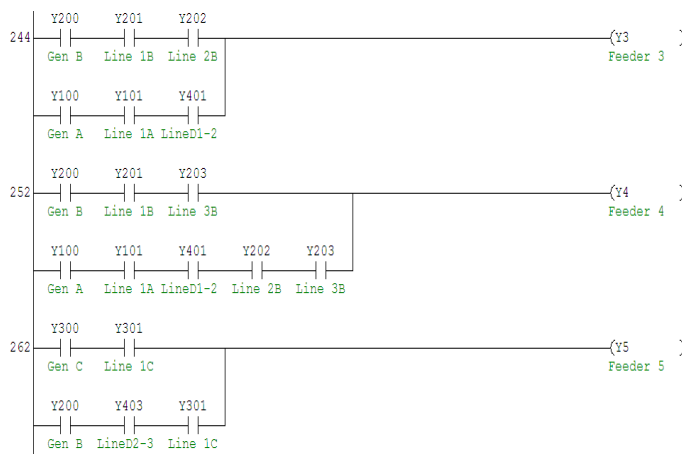


GX Developer Program Part: 7

The operating condition of feeder 3 is either presence of generator 'B' along with line '1B' and line '2B'. The second condition of feeder 3 operation is presence of generator 'A' along with line '1A' and line 'D1-2'.

In case of feeder 4, the operation can be done either through generator 'B' along with line '1B' and '3B'. Other condition of operation regarding feeder 4 is presence of generator 'A' along with line '1A', 'D1-2', '2B' and '3B'.

In part 8 of program the operating condition of feeder 5 is presence of generator 'C' along with line '1C'. The other condition of operation is presence of generator 'B' along with line 'D2-3' and '1C'.

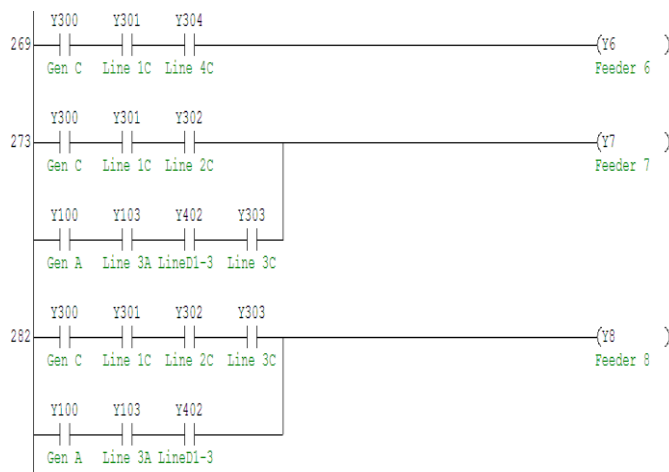


GX Developer Program Part: 8

In part 9 of program the operational condition of feeder 6 is presence of generator 'C' along with line '1C' and '4C'.

The feeder 7 operate in two conditions. The first condition of operation is presence of generator 'C' along with line '1C' and '2C'. The second condition of operation of feeder 7 is presence of generator 'A' along with line '3A', 'D1-3' and line '3C'.

The condition of operation of feeder 8 is either generator 'C' is in operation along with line '1C', '2C' and '3C'. The other condition of operation is energization of generator 'A' along with line '3A' and 'D1-3'.

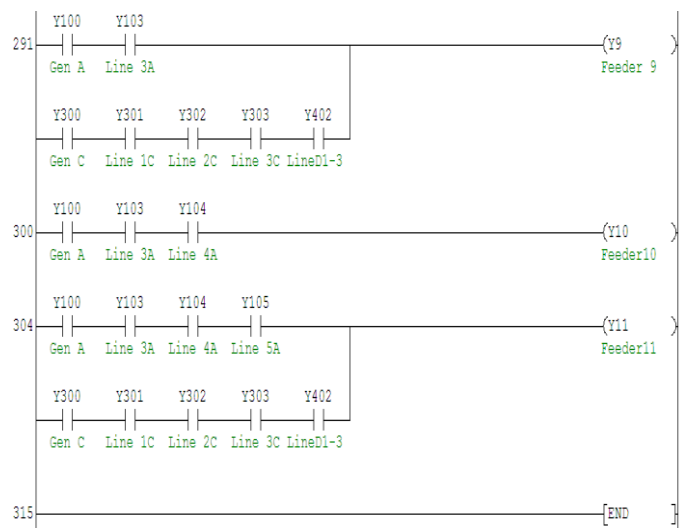


GX Developer Program Part: 9

In part 10 of program, the feeder 9 operates when there is generator 'A' in operation along with line '3A'. The other condition of operation is presence of generator 'C' along with line '1C', '2C', '3C' and 'D1-3'.

The operational condition of feeder 10 is energization of generator 'A' along with line '3A' and '4A'.

The feeder 11 operates when there is generator 'A' is energized along with line '3A', '4A' and '5A'. The other condition of operation is presence of generator 'C' along with line '1C', '2C', '3C' and line 'D1-3'.



GX Developer Program Part: 10

III. RESULTS AND OUTPUTS

In order to demonstrate whole scenario, how SCADA software change/ shift the load from one generator to other or in case line fault, consider a small distribution system, supplied power to small area working in racial fashion. Total three number of generator are present in system: Generator A 500 KVA, Generator B 200 KVA, Generator C 400 KVA. There are total eleven (11) fearers feed the load center and connected to different generators. The feeder demand is given as: feeder-1 55 KVA, feeder-2 20 KVA, feeder-3 45 KVA, feeder-4 40 KVA, feeder-5 70 KVA, feeder-6 110 KVA, feeder-7 95 KVA, feeder-8 15 KKVA, feeder-9 60 KVA, feeder-10 80 KVA and feeder-11 50 KVA. The feeders 1, 2, 9, 10 and 11 are connected with generator A. The feeders 3 and 4 are connected with generator B. The feeders 5, 6, 7 and 8 are connected with generator C.

A. Case A (Normal Operation/ All Generator ON)

The system configuration in normal condition is given below:

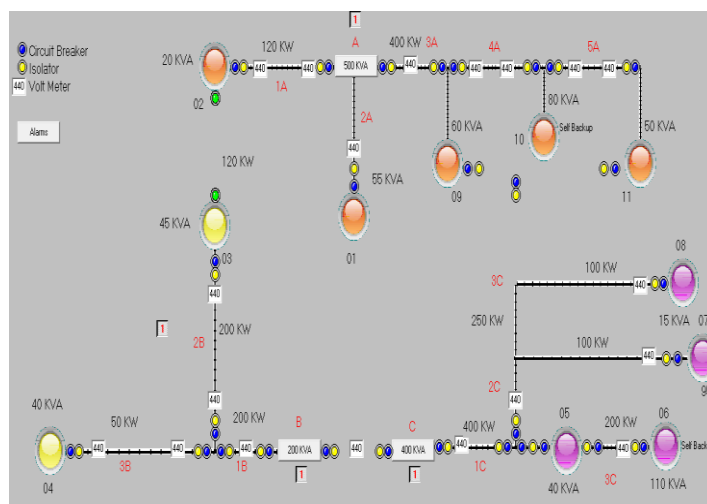


Figure 1.3: System configuration in normal condition

The suffix ‘1’ along with generator show on condition and suffix ‘0’ shows off condition of generator. The ‘MW’ capacity of each line is also mention along with line.

B. Case B (Fault at Generator A)

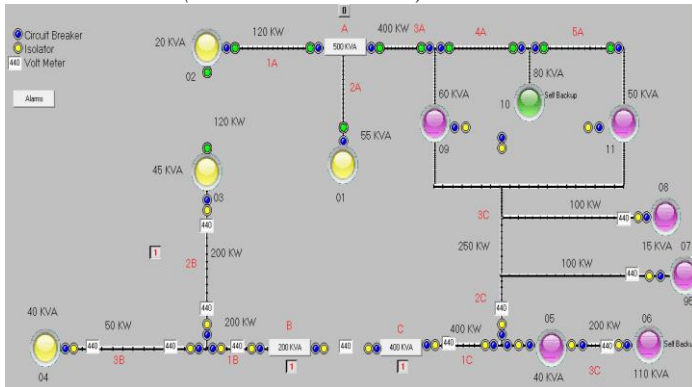


Figure 1.4: Fault at generator ‘A’

The above figure shows a faulty condition at generator ‘A’. In this condition feeder 1, 2, 9, 10 and 11 become out of order. The total demand of feeder connected to generator A is 265 kilowatt. The maximum spare power, which can be produce by generator B would be 115 kilowatt and generator C has total spare power of 140 kilowatt.

C. Case C (Fault at Generator B)

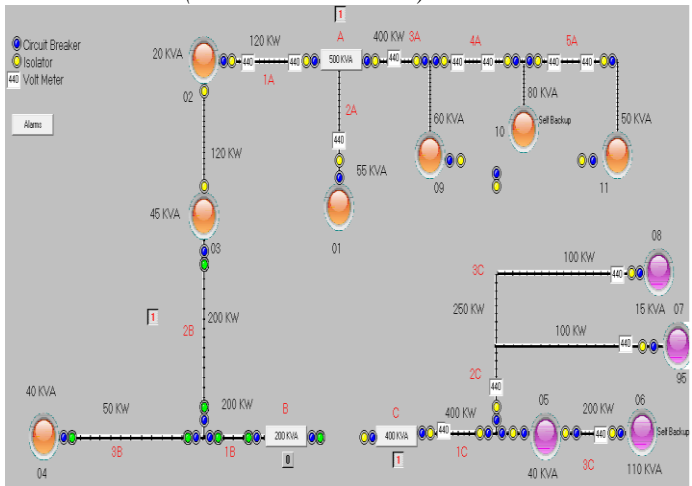


Figure 1.5: Fault at Generator B

The total power demand of feeders connected to generator B is 85 Kilowatts. The spare power that can be produced by generator A would be 235 kilowatts. The generator ‘A’ provided the power through line, which connect feeder ‘8’ and ‘2’.

D. Case D (Fault at Generator C)

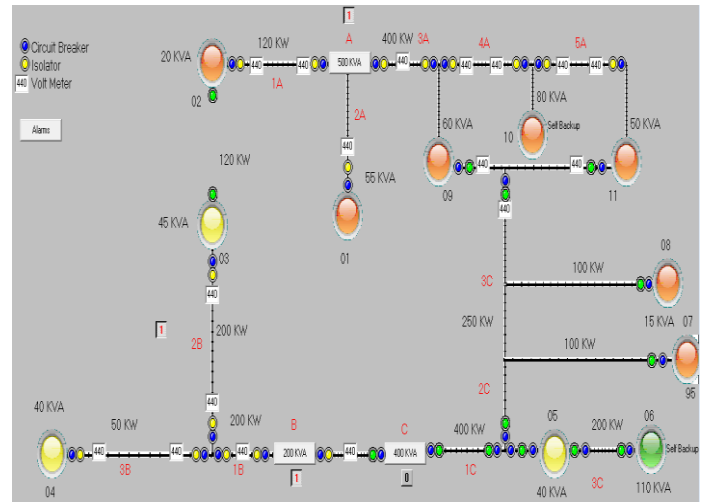


Figure 1.6: fault at generator C

The faulted condition is shown above, when fault occur at generator C. the total demand of all the feeders connected to generator C would be 260 kilowatts. The spare power that can be supplied by generator A would be 235 kilowatt and the power delivered by generator B would be 115 kilowatts. So in this condition one generator can’t fulfill the demand of all the feeders connected to generator C.

E. Case E (Fault at Generator A & B)

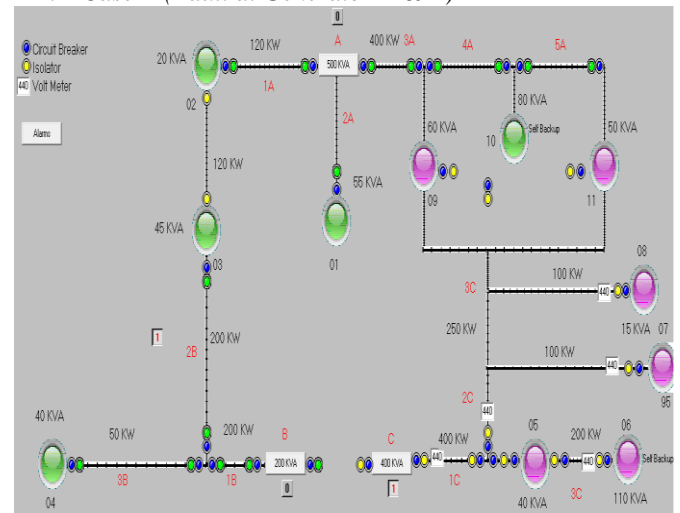


Figure 1.7: faulty at Generator A and B

The condition of fault when fault occur at generator A and generator B. In this condition majority of system will be disturb. Total seven number of feeders would be disturb. The total demand of all seven feeders would be 350 kilowatt. The spare power that can be produced by generator C is totally 140 kilowatt. So it is clear that only generator C can’t fulfill the demand of all feeders connected to generator A and generator B.

F. Case F (Fault at Generator B & C)

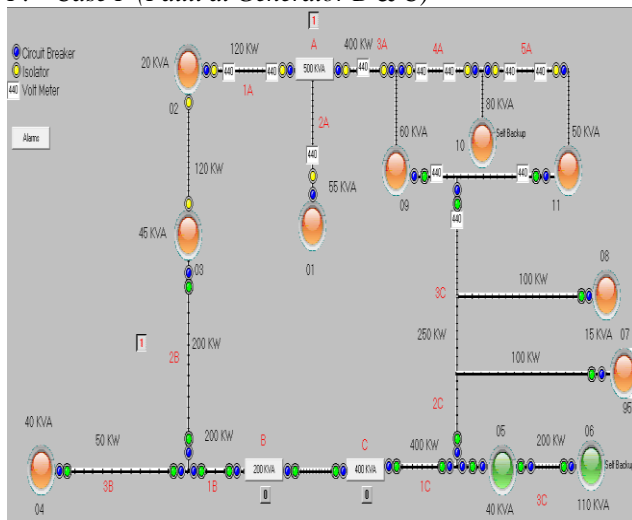


Figure 1.8: fault at generator B and C

The above mention figure show fault at generator B and generator C. In this condition total 6 number of feeders would be disturbed. The only generator that can feed in this condition is generator A. as generating capacity of generator A is 500 KVA and spare capacity of generator A would be 235 kilowatt. The total demand of all feeder connected to generator B and C would be 345 kilowatt, that can't be fulfil by generator A alone.

G. Case G (Fault at Generator A & C)

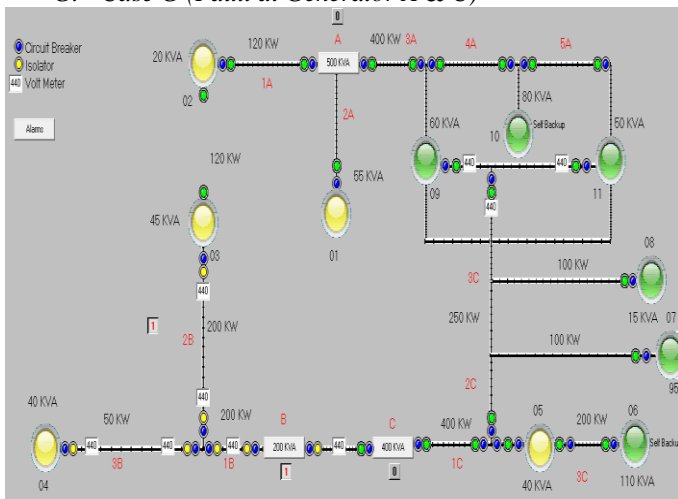


Figure 1.9: fault at generator A and C

The condition of fault at generator number A and C given below. In this condition only generator B is in working condition. It is not possible for generator B to fulfil demand of all feeders connected to generator A and B.

In this condition only limited generates would be supplied by generator B. the total generating capacity of generator B is 200 kilowatt and it has 115 kilowatt of spare power that can be supplied to feeders connected to generator A and C.

H. Case H (Fault at Line 2B)

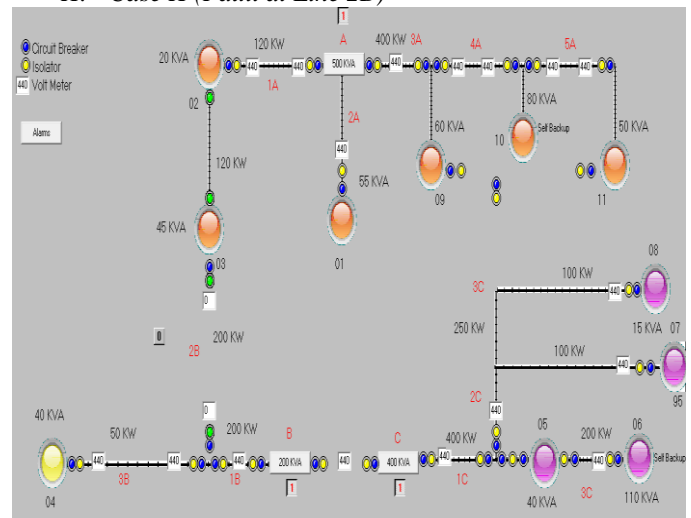


Figure 1.10: Line fault

A fault occur at line 2B, a line connect generator B with feeder number 3. In this condition only power flow to feeder 3 will be interrupted.

In this condition system consideration should be (a) is generator A has spare power to fulfil demands of feeder 3 and (b) line capacity.

CONCLUSION

The following conclusions are formulated from results obtained after implementation of proposed scheme.

- Using radial system for distribution system is more economical, but not feasible. In condition of fault majority of system would be intercepted. By adopting proposed scheme a more reliable system can be built with system ability to change configuration from radial to ring main system.
- The fault clearance (line fault) would be done automatic fashion, which is less time consuming and more efficient and reduce human effort.
- More advance system can be obtained by using recommended policy, with better human interference.

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