CALCULATION OF BUSBAR 3-PHASE FAULT CURRENTS OF AN INDUSTRIALPOWER NETWORK BY PERFORMING SHORT-CIRCUIT ANALYSIS USING ETAP SOFTWARE

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ABSTRACT: This paper provokes the idea of faults in the power system, and it is stimulated in this work. Mainly thereare two major faults that can occur in power system, these are open circuit fault and short circuit fault. Of the two faults, short circuit fault is the more dangerous because it can result in extremely high fault currents, which can have very serious consequences like electromechanical forces and thermal heating on equipment that may require replacement, as well as possibly starting fires and other similar secondary effects in the power system. Building systems are particularly vulnerable. To prevent problems from short circuits, electrical protection systems must be created to be able to identify any potential abnormal fault currents and then take corrective action to prevent issues from short circuits and to isolate the faulty section of the system in short time as it is consistent with the magnitude ofthe short circuit fault current level. This requires that the fault current be predicted for a fault in any particular location or place where the fault as occurred in the power system. This paper describes the calculation of Busbar 3- phase fault currents of an industrial power network byperforming short circuit analysis at different locations. Thisanalysis is done by using Electrical Transient AnalyzerProgram (ETAP).

KEYWORDS: Open circuit fault, Short circuit fault, Symmetrical and Unsymmetrical faults,Short Circuit Analysis, Electrical Transient Analyzer Program (ETAP)

I. INTRODUCTION:

One of the most crucial and unavoidable calculations in electrical design is the short circuit calculation. All electrical equipment must be capable of withstanding fault current fora predetermined period of time. Any accessible fault currentin the system should be able to be safely cleared by protective devices. Additionally, faults in safeguarding equipment must be fixed within the equipment's withstand time.

Symmetrical Fault: A symmetrical fault, such as a triple line fault or a triple line to ground fault, occurs when there are equal fault currents in the electrical lines with a 120- degree displacement. When the earthing switch is mistakenly left ON, a triple line fault might occur when thecircuit breaker is being switched ON. The symmetrical faultis the most severe and places heavier burden on CB.

Direct approach, impedance method, or component short circuit current method are all effective ways to address symmetrical faults. Due to its high degree of precision in low voltage networks, impedance techniqueis mostly used.

Unsymmetrical Fault: Unsymmetrical faults include single line to ground faults, double line to ground faults,and double line faults in the power system that cause unequal fault currents in the electrical lines with out of balance phase displacement. The most frequent problemis a line to ground fault, which can be caused by lightning, switching overvoltage, defective insulators, flashover across line insulators, or line insulator failure. Transformers and electrical equipment are both susceptible to LG faults. Kirchhoff's Law or the symmetrical components technique can be used to fix anasymmetrical fault.

ETAP: The Electrical Transient Analyzer Program (ETAP) is a structured computer software that makes use of common data bases and technically accuratemodels. Additionally, ETAP produces output reports that are simple to understand and applies standards that are widely acknowledged in the industry automatically.Typical data can be replaced based on request with the use of user-edited libraries. The software will compute the voltage magnitude at the faulted phase and the voltage magnitude at the healthy phase once the networkhas been modelled for 3 phase fault, single phase to ground fault, double phase to ground fault, phase to phase fault, and voltage magnitude at both phases. Additionally, it is possible to compute the minimum and maximum currents, where the minimum fault current is used to coordinate protection relays and the maximum fault current is used to calculate the circuit breakers' breaking and making ratings.[12]

The effects of faults include:(1) Dramatically dropping voltage due to extremely high fault current, (2)Destroying or damaging power system equipment due toextremely high fault current, (3) Network companies losing money due to lengthy service interruptions as repairs of the damaged equipment may take time and Industries suffering due to loss of production and inconvenience.

II. INPUT REQUIRED FOR SHORT CIRCUIT CALCULATION

The precision of the input used determines the accuracy of the ETAP output. The lowest input necessary for the ETAPmodel to execute a short circuit calculation without sacrificing the accuracy of the outcome is covered in this section. The ETAP model needs a lot of additional data to be filled in. But their specifics are irrelevant for calculatingshort circuits.

A. Grid Input:
Short circuit calculation requires source impedance and the grid's rated voltage. Grid modelling in ETAP requires the rated voltage of the grid, three phase short circuit apparent power (MVAsc), its X/R ratio, and single-phase short circuit apparent power, its X/R ratio. The utility power provider provided this information. The utility supplier typically provides two short circuit apparent power ratings (maximum and minimum values). The maximum value andlowest value must be utilized to determine the maximum and minimum available fault current, respectively.

B. Power System Network:
An electric power system network is required as it defines a network of electrical components used to supply, generate, transmit, and consume electric power.

C. Lump load Input:
In ETAP, many loads can be combined into a single lump load. Low voltage loads are typically described as lump loads in large systems. The rated power and power factor ofa lump load are considered as the total power and power factor of the group load, respectively. When configuring a lump load, kVA (% of the motor load) is entered, and ETAPcalculates the percentage constant impedance load value (static load).

D. Generator input:
In order to model a generator, it is necessary to know its rated power, rated voltage, power factor, d-axis (D-axis) subtransient reactance (Xd''), d-axis transient reactance (Xd'), d-axis and q-axis reactances (Xd and Xq), negative sequence reactance (X2), zero sequence reactance (X0), armature resistance (Ra), negative sequence resistance (R2).

E. Busbar Input:
The busbar's nominal voltage serves as the calculation's most crucial input. Based on the bus nominal voltage, ETAP determines short circuit current. The bus voltage and transformer secondary voltage are different in IEC-based applications. The bus voltage (attached to the transformer secondary) is seen by ETAP as being the same as the transformer secondary voltage.

F. Transformer Input:
To simulate a transformer in ETAP, the following data must be provided: rated voltage, rated apparent power, positive and zero sequence impedance (in%) with X/R ratio, vector group, and kind of system earthing. Basedon the load connected to the transformer and the biggest motor that will be started on the transformer, the rated apparent power is chosen. If it is necessary tominimize the fault current at the transformer's secondary, a greater impedance value than that supplied can be used to determine the transformer's impedance.

III. CALCULATION AND REPORT OF ETAP

By selecting the "Run LG, LL, LLG 3-phase Faults" icon in ETAP, short circuit calculations can be carried out. For 3-phase faults, line to ground (LG) faults, lineto line (LL) faults, and double line to ground (LLG) faults, ETAP calculates initial symmetrical RMS current, steady state RMS current, peak current, and angle between current and voltage, among other things.

The output report of ETAP contains the short circuit calculation results. The computation of the maximum available short circuit current must be done using the study case and configuration state predicted for the maximum available fault current. In a similar manner, the minimal available short circuit current is calculated by selecting the proper study case and setup status.

IV. UTILIZING THE RESULTS OF ETAP

A. Busbar selection or Design:
Switchgear busbars are built to withstand thermal and electromagnetic effects. The electromagnetic effect is made up of stress caused by bending force, electromagnetic peak forces between conductors owingto three-phase fault current, and electromagnetic peak forces between conductors due to LL fault current.

B. Over current Protection:
Short circuit analysis is done to provide necessary over current protection to the devices in the distribution system that will prevent injury to personnel, minimize damage to system components, and limit the extent andduration of service interruption during equipmentfailures, overload or short circuit.

V. SYSTEM NETWORK:

Electrical power distribution network of raw water pipeline works is as shown in below figure. The Network will get main power supply from 11kV grid, the power will further be distributed through distribution transformerTR (1.6 MVA). Major loads are raw water pump motors that are connected to the system. The power is further distributed to 415V LVIncomer Bus for feeding 415 loads connected across different bus.

Equipment Considered in Power Network:

1.Electric Grid 2.Current Transformers 3.Busbars 4.Circuit Breakers 5.Transformers 6.Cables 7.VFD 8.Motor Loads 9.Lump Loads 10.Relays 11.Air Circuit Breakers.

The equipment are modelled in ETAP software and data of respective equipment are entered. By selecting the "Run LG, LL, LLG 3-phase Faults" icon in ETAP, short circuit calculations can be carried out. Simulation is done for the following power network.

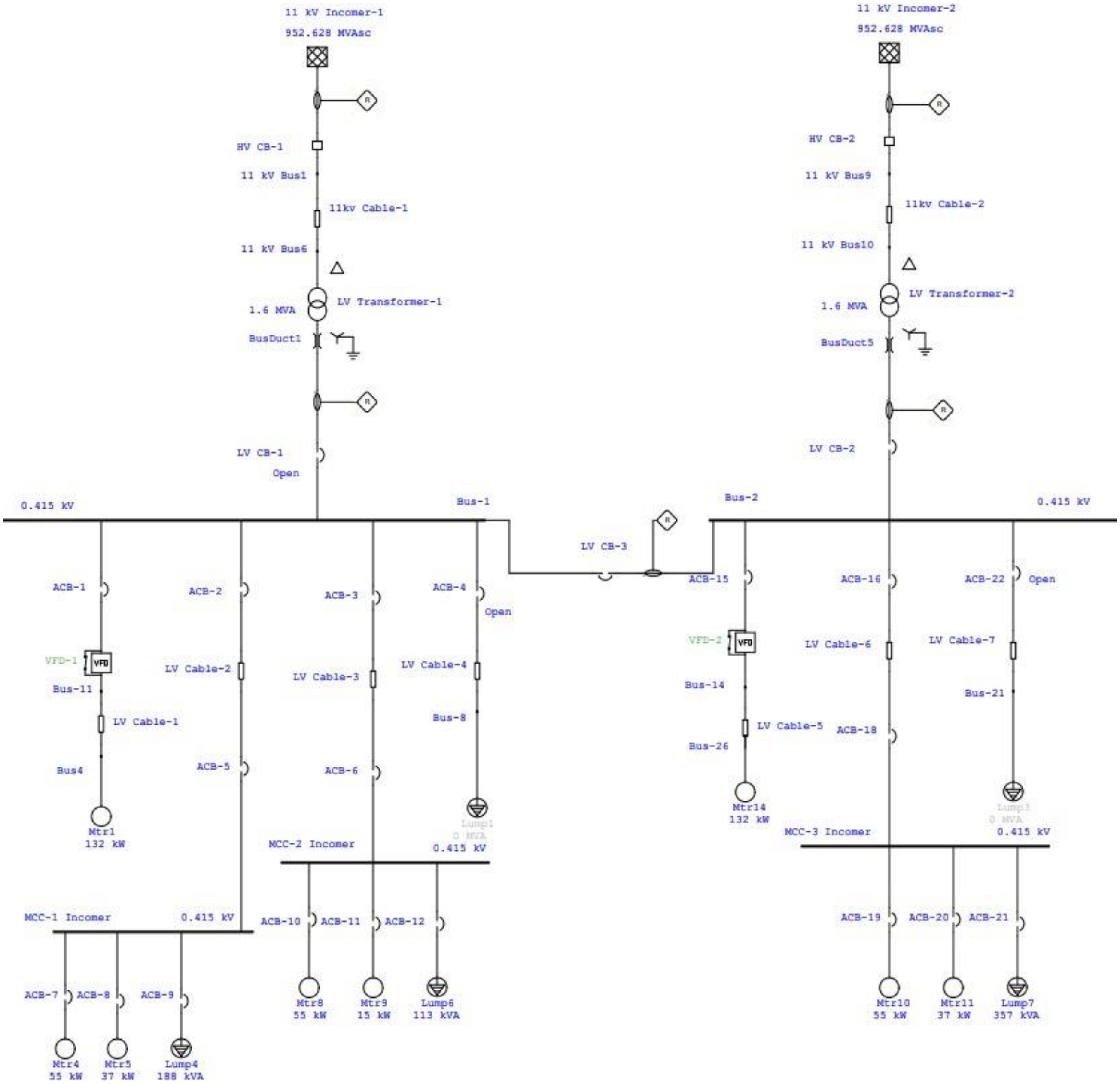

Fig-1: Typical Power Network for Simulation

VI. SHORT CIRCUIT RESULTS:

Short circuit study results for various faults are listed in below table.

Table-1: SCA Results

Bus		3-Phase Fault			Line-to-Ground Fault			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik
Bus-1	0.415	43.388	96.847	37.558	41.520	92.676	41.520	41.520
Bus-2	0.415	41.331	92.637	37.558	40.378	90.502	40.378	40.378
MCC-1 Incomer	0.415	38.367	80.896	33.252	34.599	72.951	34.599	34.599
MCC-2 Incomer	0.415	38.147	80.366	33.252	34.487	72.656	34.487	34.487
MCC-3 Incomer	0.415	38.809	84.110	34.982	36.476	79.052	36.476	36.476

Bus	Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
Bus-1	37.219	83.077	37.219	37.219	42.718	95.350	42.718	42.718
Bus-2	35.654	79.914	35.654	35.654	41.093	92.105	41.093	41.093
MCC-1 Incomer	32.919	69.408	32.919	32.919	36.818	77.630	36.818	36.818
MCC-2 Incomer	32.743	68.982	32.743	32.743	36.654	77.222	36.654	36.654
MCC-3 Incomer	33.467	72.530	33.467	33.467	37.851	82.032	37.851	37.851

In above table, I"k indicates maximum fault currents and Ik indicates minimum fault currents in kA. The results of maximum and minimum fault currents are used for different applications i.e., maximum faults currents are used for Busbar design parameters and minimum fault currents are used to provide optimal relay settings for protection coordination that are connected in the network.

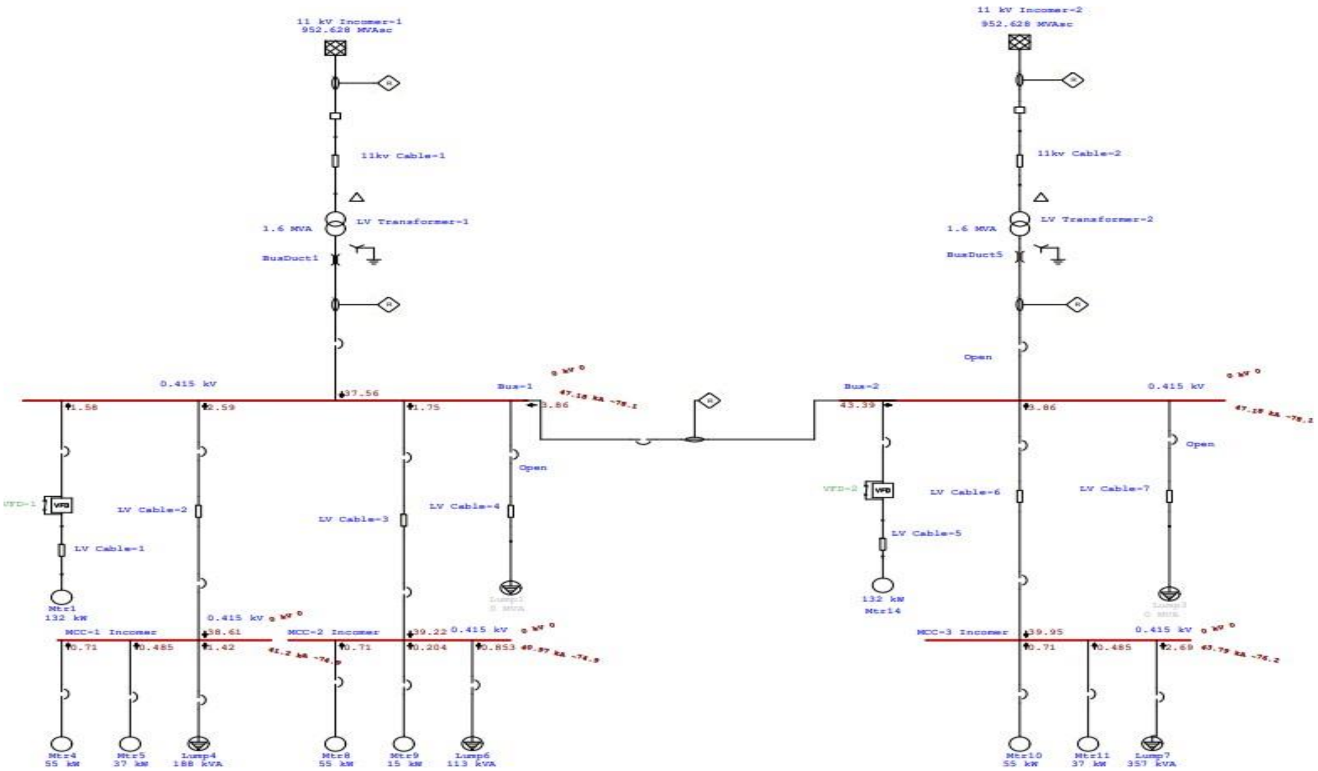

Fig-2: ETAP Modelled SLD after Simulation

VII. RELAY COORDINATION:

The coordination of relays is crucial for the safety of the electrical system. We need to properly coordinate the relays with the right relay settings in order to provide the necessary protection. Relay configurations are made in a way that ensures proper coordination along numerous series networks. Stages for fault clearance: 1) Occurrence of fault 2) Measurement by instrument transformer 3) Analysis by protection relay for initiating selective tripping 4) Switchgear to clear the fault 5) Relays are installed not to prevent the faults but to isolate the faults and to minimize the damage.

Relay co-ordination can be done by selecting a proper plug setting and the time multiplication setting of the relay, considering fault current at the relay locations. For a given fault current, the operating time of relay is jointly determined by its plug and time multiplier settings. Thus, these type of relays will be most suitable for proper coordination.[3]

VIII. RESULTS AND DISCUSSION:

Let us consider above power network system for relay coordination using ETAP software. In ETAP we have to designthe circuit by calculation for certain values in the system and some will be taken from the IEC standards. In designed system, we need to run the following analysis for relay coordination. They are:

1) Load flow analysis

2) Short circuit analysis

3) CT Selection

4) Relay coordination

By this we can have proper sequential operation of the relay by this we can isolate the fault position for the healthier network

8.1 Relay Tripping Sequence for Fault at MCC-1 Incomer:

The sequence of operation of Air-circuit breakers and relays are shown below.

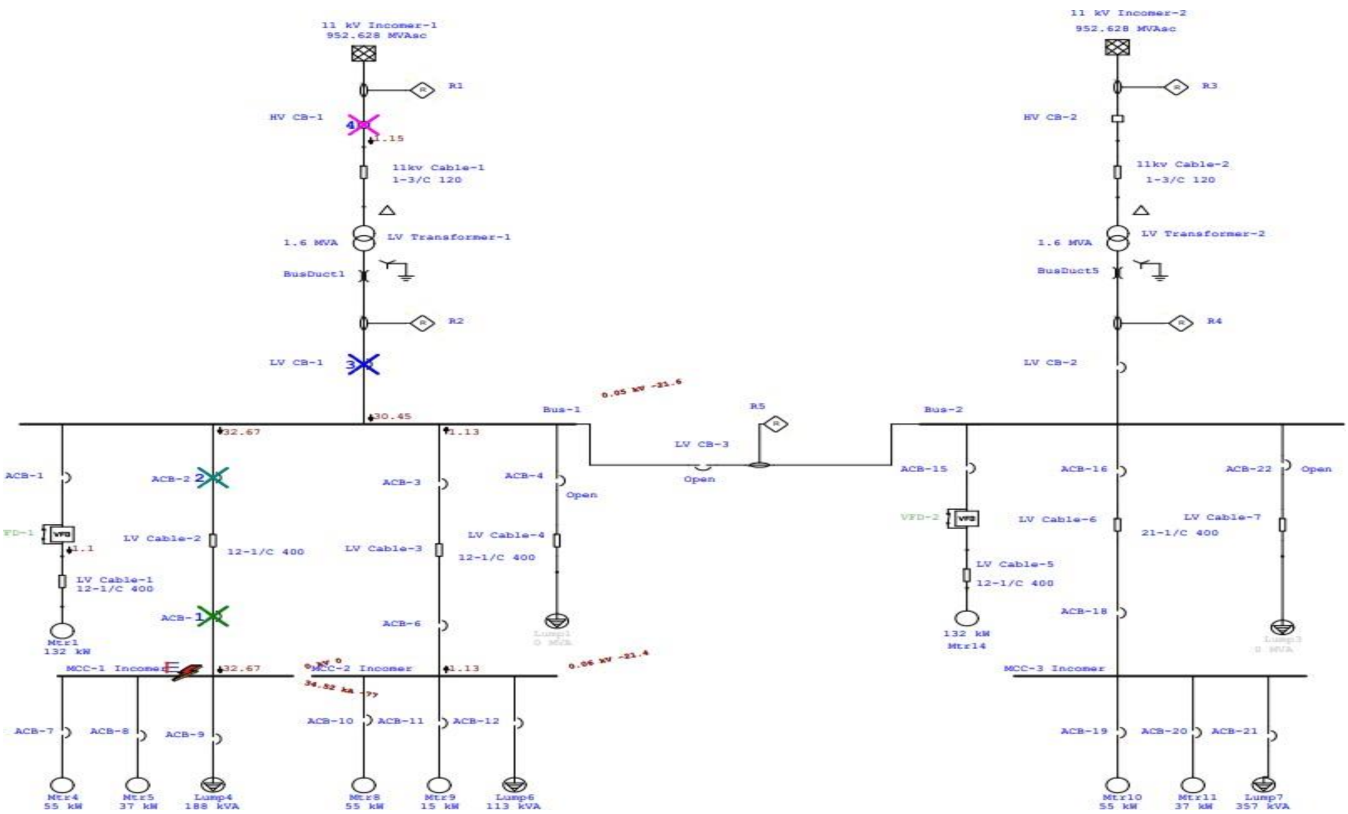

Fig-3 Sequence of Operation

Table-2 Sequence of Operation

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
120	ACB-5	32.671	80.0	120	Phase
240	ACB-2	32.671	160	240	Phase
600	R2	30.451	600		Phase - OC1 - 50
610	LV CB-1		10.0		Tripped by R2 Phase - OC1 - 50
865	R1	1.149	865		Phase - OC1 - 51
875	HV CB-1		10.0		Tripped by R1 Phase - OC1 - 51

8.2 Relay Tripping Sequence for Fault at MCC-3 Incomer:

The sequence of operation of Air-circuit breakers and relays are shown below.

Table-3 Sequence of Operation

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
180	ACB-18	35.994	120	180	Phase
240	ACB-16	35.994	160	240	Phase
400	R5	35.994	400		Phase - OC1 - 50
410	LV CB-3		10.0		Tripped by R5 Phase - OC1 - 50
600	R2	31.972	600		Phase - OC1 - 50
610	LV CB-1		10.0		Tripped by R2 Phase - OC1 - 50
848	R1	1.206	848		Phase - OC1 - 51
858	HV CB-1		10.0		Tripped by R1 Phase - OC1 - 51

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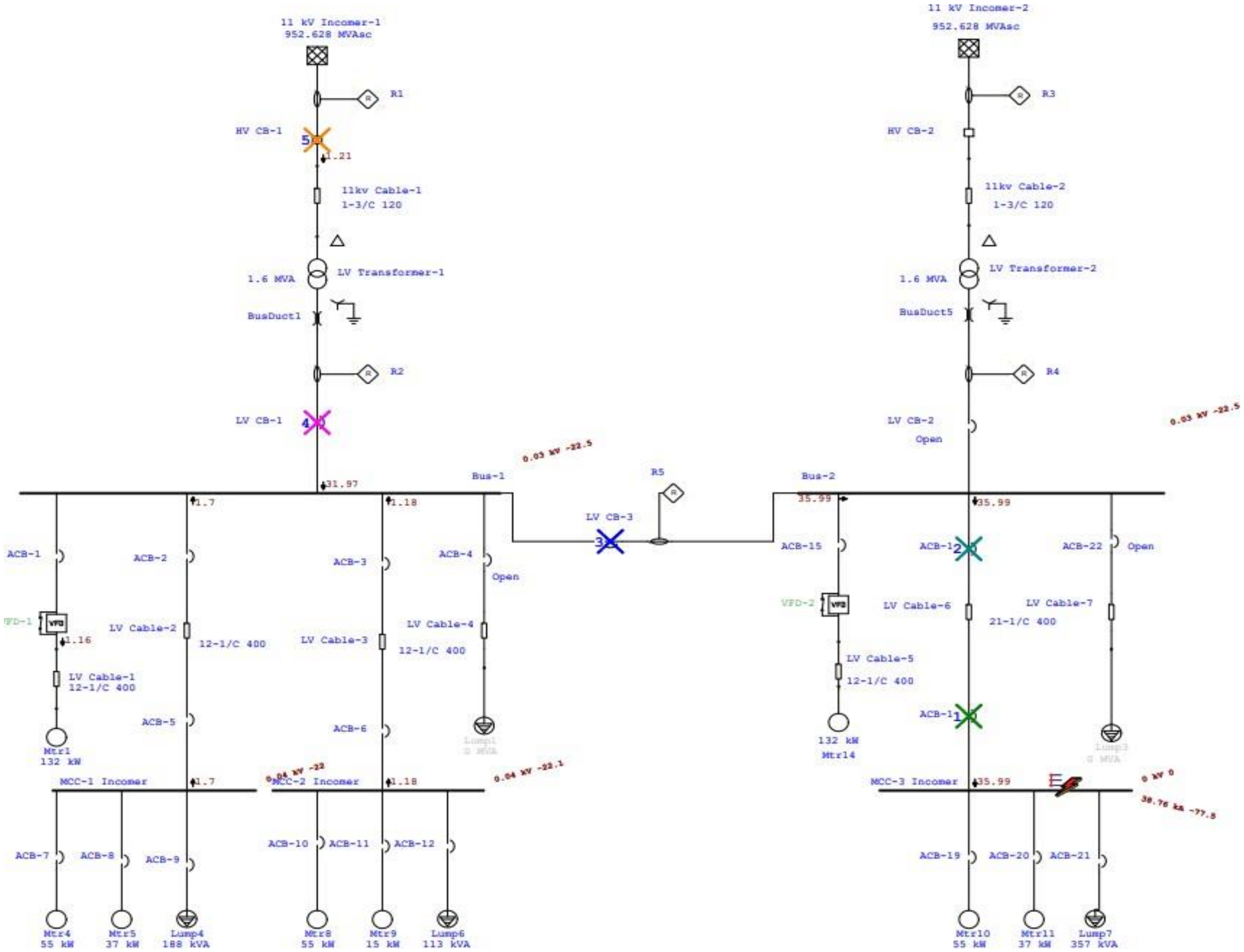
Fig-4 Sequence of Operation



IX. CONCLUSION:

The short circuit analysis is very important to find the fault magnitude at various buses in the power network. The maximum and minimum short circuit currents are obtained when three phase hand single line to ground fault are created, and the values are validated. The short circuit calculation is done using ETAP software and theresults generated from the short circuit analysis are promising and are helpful to understand nature andwave shape of short circuit current for proper sizing of distribution network electrical equipment and the valueswill be used to provide optimal relay settings for protection coordination in the power system. The relaysare the major protection devices in distribution system. The relay coordination in radial network is highly constrained optimization problem. The relays in the power system are to be coordinated properly so as to provide primary protection as well as back up protection. In this project, short circuit analysis is donefor a typical power network.Short circuit currents of the switchgears are found and well maintained within the limits of switchgear short circuit withstand capabilities and also relay coordination is obtained for considered power network.

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