

Load Flow and Short Circuit Analysis for a Data Centre

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Abstract: For industrial buildings like Data centres maintaining power outages is a crucial role. Even a power outage for 1-minute leads to loss of huge numbers of Data. So, completely relying on grid for power supply is not efficient. In this paper load flow and short circuit analysis are performed for a Data Centre under different operating scenarios to ensure the system reliability. As a result, it checks whether all bus voltages are within the limit.

Keywords: Different operating scenarios, Load flow analysis, Reliable power supply.

I. INTRODUCTION

In the modern digital era, Data Centres have become a necessary infrastructure to support cloud computing, data storage, etc. these facilities require a reliable and uninterrupted power supply, as even a short duration of power outage can lead to high data losses. So, completely depending on utility grid for power supply is not sufficient to ensure reliable power supply. To address this challenge, backup supplies such as UPS and generators are used to maintain continuous power supply during grid outage. The effectiveness of these backup systems depends on the time at which they are switched ON to provide continuity. To overcome these challenges, this project focuses on performing detailed load flow and short circuit analysis for a data centre under different modes of supply. All the analysis are performed using ETAP (Electrical Transient Analyser Program) software.

The study aims to:

- Ensure whether the all-bus voltages are within the limit.
- Analyse system performance during grid outages.

II. POWER DISTRIBUTION ARCHITECTURE OF THE DATA CENTRE

The power distribution in data centre is designed well, to maintain the continuous power supply to the critical loads and data racks during power outages. It is divided into three boards namely Main Distribution Board (MDB), Sub Main Distribution Board (SMDB), and Output Board (OB) as shown in fig. 1.

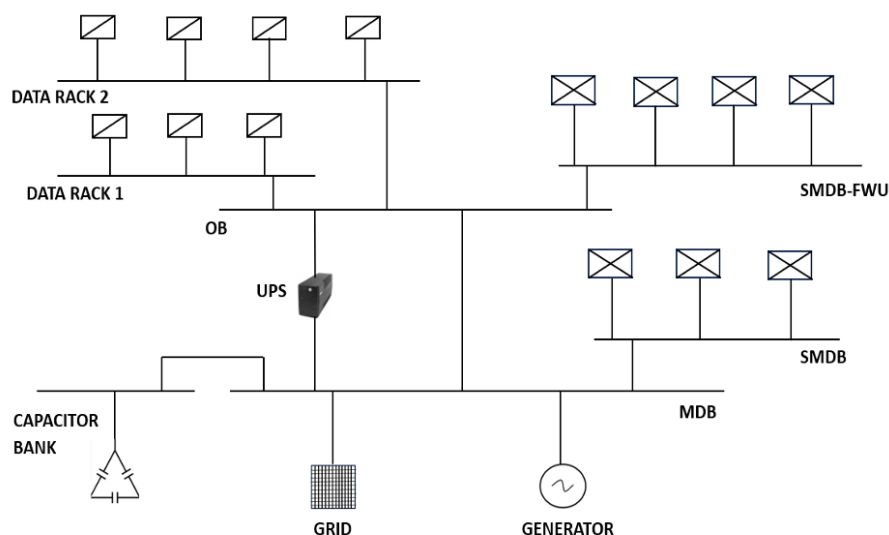


Fig. 1. Power distribution architecture of the Data Centre

III. DIFFERENT OPERATING SCENARIOS

The Data Centre has a lot of servers runs at a time. Even a small power outage can lead to huge data losses. To achieve continuous supply to critical loads the system operates in three modes namely:

- UPS mode
- UPS Bypass mode
- Generator mode

A. UPS Mode (Normal Operating Mode)

During normal operation, the grid supplies the data centre through the UPS by using the UPS line. If power outages happen in the grid, it takes a small delay for the generator to start and take over the load. To eliminate this delay, the UPS continuously monitors the incoming power supply from the grid and turns ON immediately after the grid fails. It will continue supplying the critical loads until the generator reaches the rated speed and synchronization. A capacitor bank is connected to the MDB panel to provide reactive power compensation for the system as shown in fig. 2. During this mode the circuit breakers at bypass line and at the side of generator are open to disconnect the generator

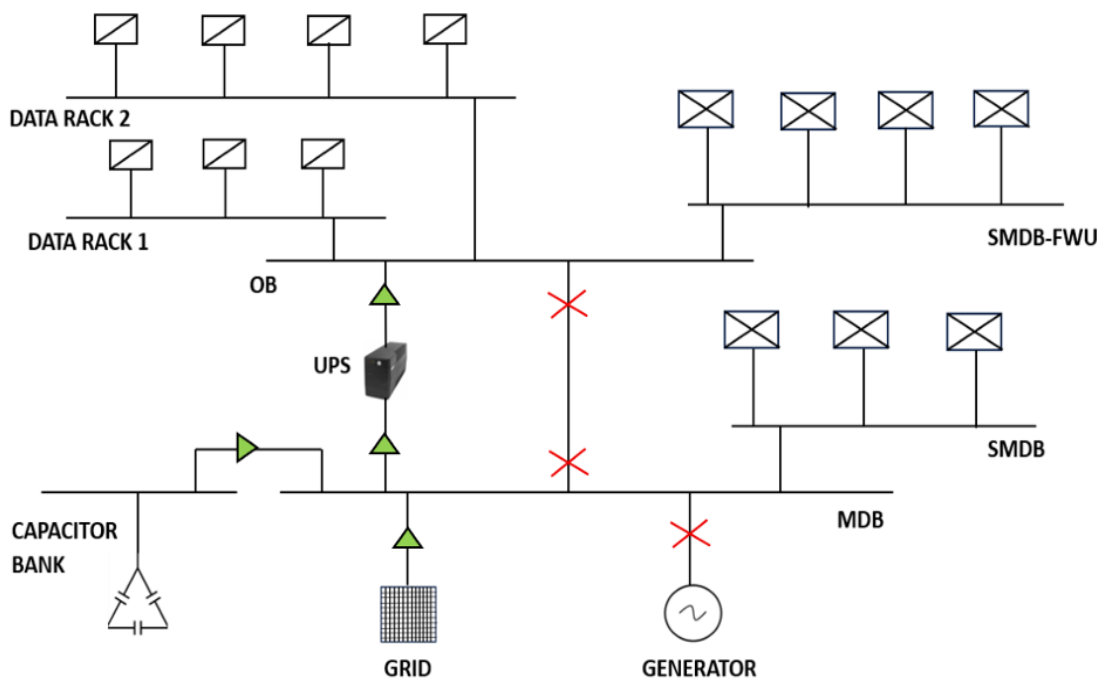


Fig. 2. Block diagram of UPS mode

B. Generator Mode

In this mode of operation only the generator supplies all the critical loads in the data centre as shown in fig. 3. Both the grid and UPS are disconnected from the network. This happens after the transition of grid to UPS, once the generator reaches its rated speed and voltage. The capacitor bank is also disconnected from the network as the generator can handle both real and reactive power, if it is connected it leads to over voltage. During this mode the power supply to OB takes place through the Bypass line. Once the grid starts supplying the load is transferred to the grid and the generator turns OFF. The circuit breakers disconnect the generator and the bypass line from the network and the grid starts supplying through the UPS line.

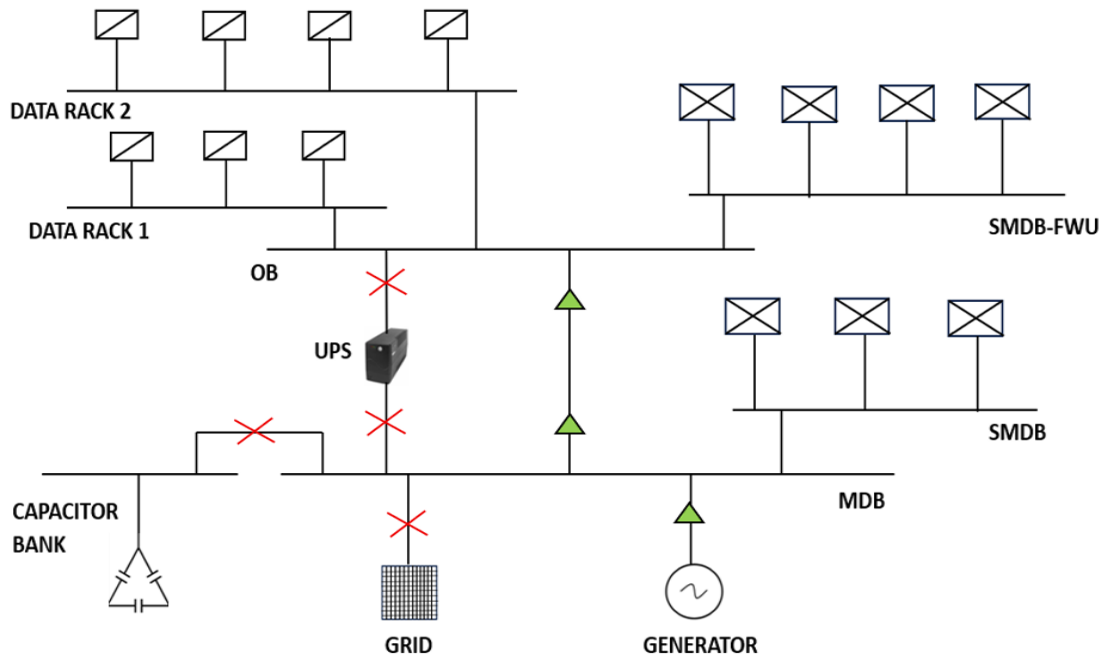


Fig. 3. Block diagram of Generator mode

C. UPS Bypass mode

In this mode the power is directly supplied by the grid as shown in fig. 4. During maintenance or failure of UPS, the grid supplies the power through the Bypass line. This allows the technicians to perform maintenance operations on the UPS without disturbing the power supply to critical loads. A capacitor bank is connected in this mode to maintain the voltage stability and reactive power compensation. Once the maintenance is completed, the supply is transferred to UPS line smoothly.

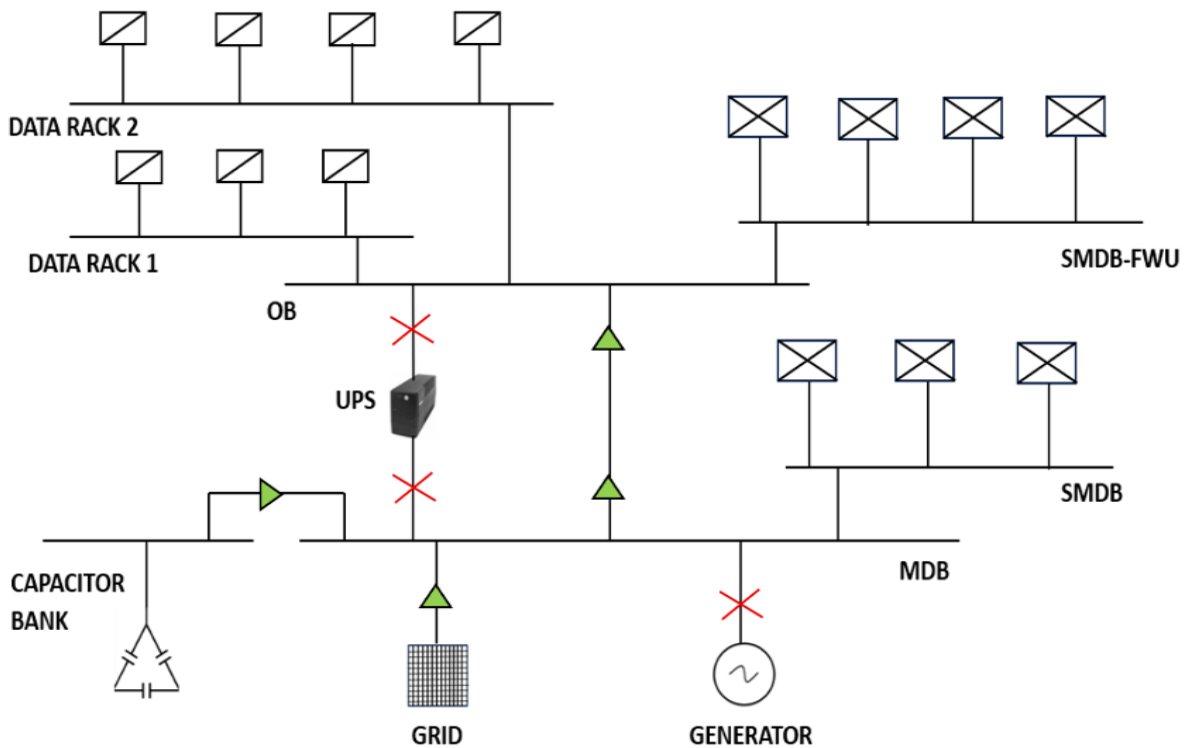


Fig. 4. Block diagram of Generator mode

IV. RESULTS AND DISCUSSION
A. RESULTS OF LOAD FLOW ANALYSIS

The Load flow analysis for the three different modes of operation of the Data Centre is performed using ETAP and the results of the three modes are tabulated below.

TABLE I RESULTS OF LOAD FLOW ANALYSIS FOR UPS MODE

BUS	NOMINAL VOLTAGE (kV)	VOLTAGE (kV)	PERCENTAGE
MDB	0.4 kV	0.405 kV	101.1%
SMDB	0.4 kV	0.404 kV	101%
OB	0.4 kV	0.405 kV	101.1%
SMDB-FWU-02	0.4 kV	0.4 kV	100.1%
SMDB-FWU-01	0.4 kV	0.403 kV	100.3%
BB-E-01	0.4 kV	0.405 kV	101.1%
BB-02	0.4 kV	0.405 kV	101.1%

TABLE II RESULTS OF LOAD FLOW ANALYSIS FOR BYPASS MODE

BUS	NOMINAL VOLTAGE (kV)	VOLTAGE (kV)	PERCENTAGE
MDB	0.4 kV	0.405 kV	101.1%
SMDB	0.4 kV	0.404 kV	101%
OB	0.4 kV	0.405 kV	101.1%
SMDB-FWU-02	0.4 kV	0.4 kV	100.1%
SMDB-FWU-01	0.4 kV	0.403 kV	100.3%
BB-E-01	0.4 kV	0.405 kV	101.1%
BB-02	0.4 kV	0.405 kV	101.1%

TABLE III RESULTS OF LOAD FLOW ANALYSIS FOR GENERATOR MODE

BUS	NOMINAL VOLTAGE (kV)	VOLTAGE (kV)	PERCENTAGE
MDB	0.4 kV	0.398 kV	99.45%
SMDB	0.4 kV	0.397 kV	99.28%
OB	0.4 kV	0.398 kV	99.45%
SMDB-FWU-02	0.4 kV	0.394 kV	98.4%
SMDB-FWU-01	0.4 kV	0.396 kV	99.08%
BB-E-01	0.4 kV	0.398 kV	99.45%
BB-02	0.4 kV	0.398 kV	99.45%

The load flow results from Table 1, Table 2, Table 3 shows that all the bus voltages are within $\pm 5\%$ of the nominal value as per the IEEE 3002.2-2018 standard. Hence the system operates stably without any overvoltage or undervoltage.

B. RESULTS OF SHORT CIRCUIT ANALYSIS

The Short Circuit Analysis for the three different operating modes of the Data Centre is performed using ETAP. The Magnitudes of fault current at all buses are tabulated below.

TABLE IV RESULTS OF SHORT CIRCUIT ANALYSIS FOR UPS MODE

BUS	RATED LIMIT	L-L-G FAULT	3 PHASE FAULT
MDB	65 KA	38.278 KA	40.211 KA
SMDB	36 KA	14.44 KA	19.02 KA
OB	50 KA	41.203 KA	43.284 KA
SMDB-FWU-02	36 KA	2.44 KA	3.481 KA
SMDB-FWU-01	36 KA	2.462 KA	5.863 KA

TABLE V RESULTS OF SHORT CIRCUIT ANALYSIS FOR BYPASS MODE

BUS	RATED LIMIT	L-L-G FAULT	3 PHASE FAULT
MDB	65 KA	38.29 KA	40.25 KA
SMDB	36 KA	14.44 KA	19.025 KA
OB	50 KA	38.29 KA	40.25 KA
SMDB-FWU-02	36 KA	2.436 KA	3.475 KA
SMDB-FWU-01	36 KA	2.458 KA	5.84 KA

TABLE VI RESULTS OF SHORT CIRCUIT ANALYSIS FOR GENERATOR MODE

BUS	RATED LIMIT	L-L-G FAULT	3 PHASE FAULT
MDB	65 KA	57.317 KA	35.136 KA
SMDB	36 KA	16.17 KA	18.19 KA
OB	50 KA	57.317 KA	35.136 KA
SMDB-FWU-02	36 KA	2.466 KA	3.464 KA
SMDB-FWU-01	36 KA	2.506 KA	5.798 KA

The Results from the table 4, table 5 and table 6 shows that the short circuit current at all the buses remains within the rated current value. This indicates that the system is adequately designed to handle fault conditions without exceeding the thermal or mechanical withstand capabilities of the equipment

V. CONCLUSION

The load flow and short circuit studies are the important studies in power system analysis. These studies help to determine the performance of the system. In this project, the load flow and short circuit analysis are carried out for the three different operating modes of the data centre. The load flow results shows that all the bus voltages are within $\pm 5\%$ of the nominal value, ensures stable operation. The short circuit analysis results shows that the fault current levels at all buses are within the rated limits. Hence the system equipment's can able to withstand the faults currents that happening due to unexpected faults.

The results obtained from the load flow and short circuit analysis can be used for selecting appropriate ratings of relays, circuit breakers, and other protection devices. Using the short circuit current data, relay coordination can be performed to achieve proper sequence of operation during fault conditions, minimizing equipment damage and system downtime. Further studies like Arc Flash are also performed to generate Arc Flash Labels, to enhance safety.

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