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Power System Analysis and Relay Coordination for an Industrial Distribution System

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Abstract: The Power System is getting advanced day by day. Also, to meet the load demand, many types of equipment like generators, transformers, motors, etc are added to the system. With the addition of all this equipment. Analysis of the load flow study based on bus data, line data, source data and load data. based on this study we know about voltage magnitude, voltage angle, real/reactive power, current flow and power losses in the system. we also perform a short circuit study, based on this data we check device duty and verify short circuit ratings of switchgear, based on the short circuit result we perform relay coordination. Relay coordination determines the relay settings to give adequate operating time at max & min fault levels, protect the equipment from damage during a fault situation, and isolate a faulty part. So that's the reason we study load flow analysis, short circuit analysis and relay coordination, to improve the system efficiency and the operation during fault conditions, all studies are performed on ETAP.

Keywords: Load Flow, Short Circuit, Relay Coordination, Power System Analysis

I. INTRODUCTION

An industrial power system's work demand is high, at that time a single type of fault in the system is not acceptable and is a danger to the system So, with the help of ETAP software and perform a load flow study, short circuit study, and relay coordination to analyse the power system.
this study is based on an industrial power system, that's why we take a cement plant to analyse and perform these studies. (Load flow, short circuit and relay coordination).

II. LOAD FLOW STUDY

The first of the study is load flow analysis. A three-phase ac power system has active power (P) and reactive power (Q) flow from the generating stations to load through different network buses These powers are supplied by generators and Grid. A study state analysis of a power system is called Load Flow or Power Flow [1].

Load flow (LF) is one of the most important parts to study and analyse power system operation. In this research paper, a study for load flow analysis in industrial power system (IPS) is presented [2]. And load flow study is based on ETAP software, the calculation method is Adaptive Newton Raphson (ANR). To perform this study, we need the data of the generator, transformer, cables, connected load, the voltage level of the system, etc.

With the help of ETAP software, we perform a load flow study according to the industrial power system, a system that has a grid as a source of 33 kV and a generator for an emergency condition. the plant has three different voltage levels at bus voltage 11 kV, 6.6 kV and 0.415 kV. on a 6.6 kV panel connected load are high voltage motors and capacitor banks, so in that study of load flow analysis, so we notice that at 6.6kV bus 1700kW motor have not capacitor bank and the motor have a poor power factor, a motor also feed a reactive power in the system so we recommended a 600 kVAr capacitor bank, as par study, we perform a load flow in 2 cases with a capacitor bank and without capacitor bank and results shown in figures.

These figures show major differences in power factor, the power factor is near unity and it also improves the voltage profile of the 6.6 kV bus and also compensates reactive power of the system.

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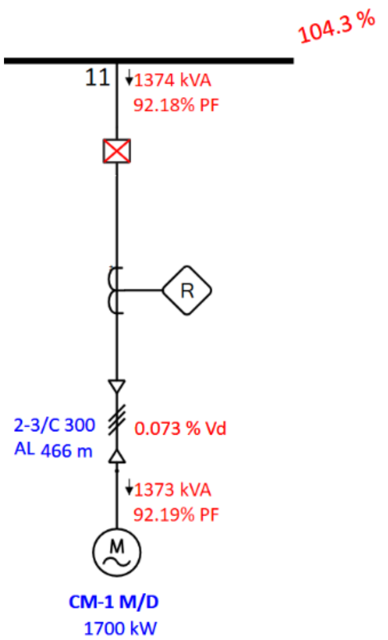

Fig. 1 motor feeder without capacitor bank

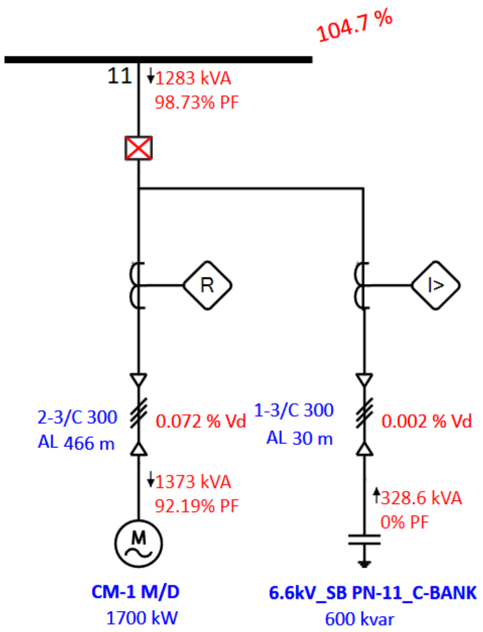

Fig. 2 motor feeder with capacitor bank

III. SHORT CIRCUIT STUDY

Short circuit studies in power systems are a basic step in the planning of industrial plants. Based on such results and studies, protective device (relay) setting and coordination are being carried out, switchgear components are constructed, manufactured and installed, etc. The study is performed using ETAP software [3].

A fault usually results in a high current flowing through the lines and if adequate protection is not taken, may result in damage to the power apparatus. Considering our system, this cement plant has three 2 MVA transformers, and it connects with three PCC respectively. But in some time, the 2 * 2 MVA transformer runs in parallel operation because a high load demand in system. As per a short circuit study, notice fault current Exceed their breaker breaking capacity is shown in the figure.

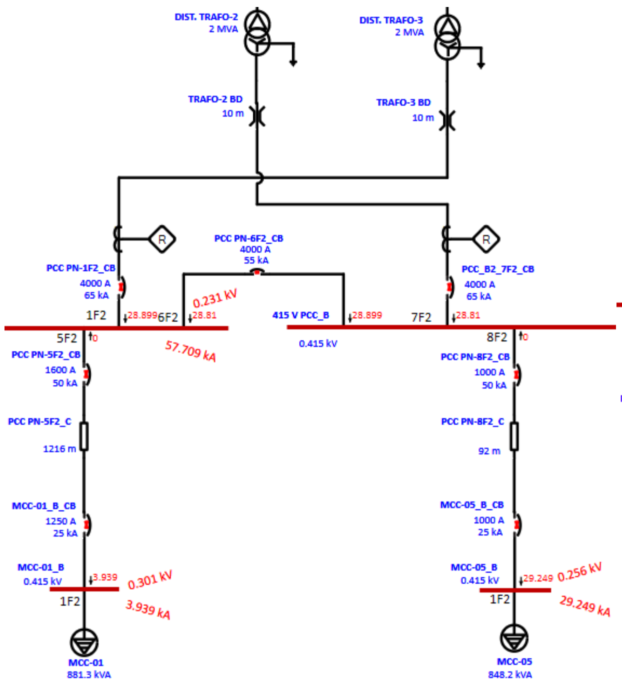

Fig. 3 parallel operation of 2 * 2 MVA transformer

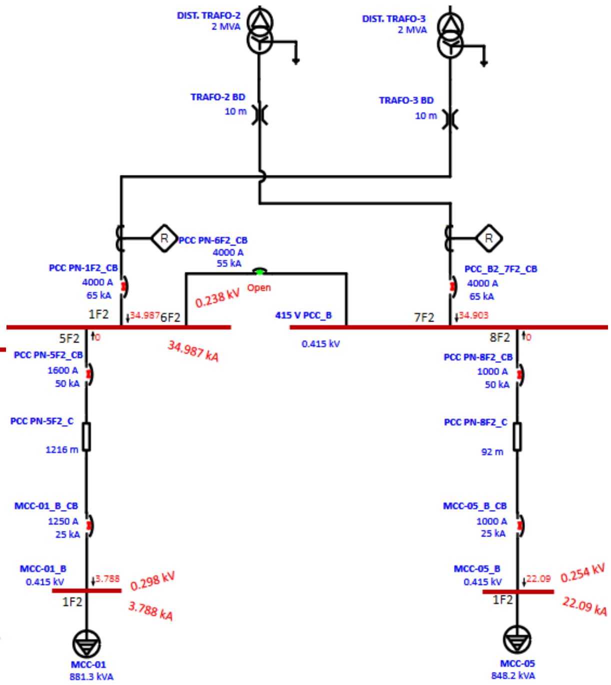

Fig. 4 Transformer in standalone mode

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The value of short circuit current exceeds the switchgear withstand capacity, in the case of LG and a 3-phase fault occurs, this is harmful to our switchgear.

As per the results, we give some suggestions to the cement plant

- we can open this bus coupler and run the transformer to standalone mode to limit fault current. If a parallel operation is not required (Figure-4)
- replace the existing circuit breaker with a new circuit breaker of higher withstand capacity (this is not economically viable)
- replacing bus duct at the secondary side of distribution transformer-2 and 3 with 2 core X 300 sq. mm of 150m long cable. Increasing impedance in the path will reduce the fault current. (Figure-5)

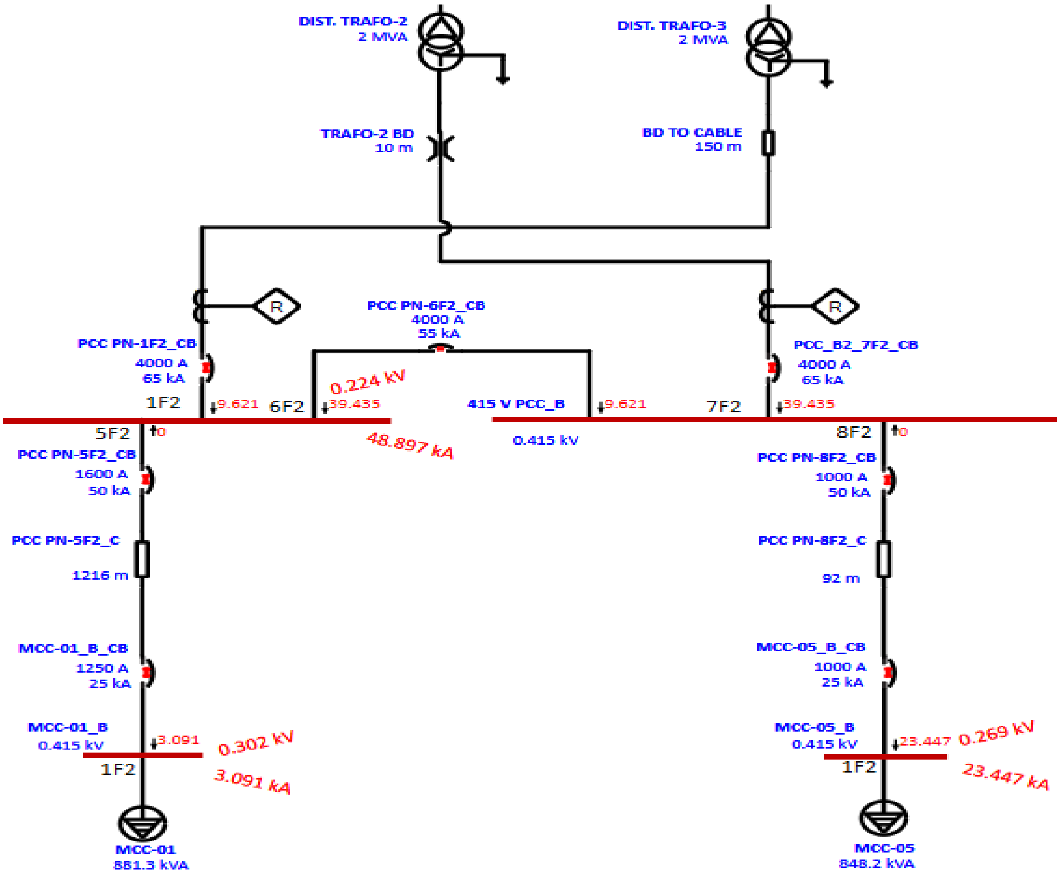

Fig. 5 short circuit results after replacing bus duct to cable

IV. RELAY COORDINATION

In any power system network, protection should be designed such that protective relays isolate the faulted portion of the network at the earliest, to prevent equipment damage, and injury to operators and to ensure minimum system disruption enabling continuity of service to a healthy portion of the network. In case of failure of primary relays, backup relays operate after sufficient time discrimination. The protective relay should be able to discriminate between normal, abnormal and fault conditions [4].

To determine the relay settings to give the adequate operating time at max & min fault levels and protect the equipment from damage during a fault situation. A Proper selection of relay settings against the derived fault level of the system for Proper discrimination between faulty sections. The settings of various Protective devices are calculated based on fault currents evaluated from the short circuit study.

Relay coordination basis on 3-methods

- time grading - we grade the LT downstream to Upmost HT upstream with time to isolate faulty parts with accurate discrimination of the time.
- current grading - we grade the LT downstream to Upmost HT upstream with the current to isolate faulty parts with accurate discrimination of the current.
- time & current grading - Combination of time & current grade for the batter resolution of the Trip devices.

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A. Plug setting

Pick up is also called Plug setting (PS), Relay current setting, and Pickup set. It is the minimum value of an actuating quantity at which the relay starts operating.

B. Time Multiplier Setting (TMS)

To calculate the TSM of the protective relay following equations are used.

Top = T0 + Td

$$\text{Desired TMS setting} = \frac{\text{Desired relay operating time, } T_{op}}{\text{Relay operating time } T_M @ \text{ selected PSM and TMS} = 1.0}$$

Were,

Top = Desired operating time

T0 = Downstream relay/release time

Td = Discrimination in time

C. Example of Trip Unit Setting calculation

Full load ampere - 370 A

Circuit breaker Rating - 800 A

Long Term protection (Ir) = (1.1 * FLA) / CT ratio

= (1.1 * 370)/ 800

= 0.508 = 0.5 * In

Short Term Protection (Isd) = (4 * FLA) / CB Rating

= (4 * 370) / 800

= 1.85 * In (for lump load)

Short Term Protection (Isd) = (4 * FLA / CB Rating)/Ir (if Ir is a Reference)

= (4 * 370 / 800) / 0.5

= 3.7 * Ir

Incomer feeder Release (Isd) = (1.5 * high instantaneous setting of downstream)/CB rating

= (1.5 * 1192)/800

= 2.235 * In

Instantaneous protection (Ii) = (10 * FLA) / CB rating

= (10 * 370) / 800

= 4.62 * In

Ground fault protection = (0.2 * FLA) / CB rating

= (0.2 * 370) / 800

= 0.09 * In = 0.1 X In

Time delay: If PCC Distribution load (lighting load etc.) is connected give 200ms-300ms time delay. That's why,

Tsd (Time delay) = 0.2 + downstream time delay

D. Example of Relay Setting calculation

Full load ampere = 2667 A

CT ratio = 4000/1 A

Phase overcurrent protection:

Fault current (If) = 39.734 kA

I> (Plug Setting) = (1.1 * FLA)/CT Ratio

= (1.1 * 2667)/4000

= 0.733 * In (2800 A)

Operating Characteristic = IEC Extremely Inverse

Time Dial (TMS) = (Required operating time)/ (operating time at TMS 1 for If)

= (400ms) /(819ms)

= 0.49

I>> (instantaneous) Plug setting = (1.3 * highest high set of outgoing feeders)/CTR

= (1.3 * 1192)/4000

= 0.387 * In (1200A)

T>> Time delay = (0.2 + downstream time delay)

= 0.2 + 0.2 (down Stream time delay)

= 0.4

For earth fault calculation (I0>) = (0.2 * FLA)/ CT Ratio

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= (0.2 * 2667)/4000
= 0.13 sec
Earth fault (I0>>) = 0.2 + downstream time delay
= 0.2 + 0.2
= 0.4 sec

All the settings of relay and Trip Unit calculations are based on this method and calculated settings adopted in the system.

E. Sequence of operation

Sequence-of-Operation (SQOP) in ETAP software evaluates, verifies, and confirms the operation and selectivity of the protective devices for different types of faults at a location directly from the one-line diagram. A sequence of Operation provides a system solution for an accurate and realistic operating time and state of protective devices, such as relay, fuse, circuit breaker, trip devices, contactor etc. The operation time is calculated for each protective device based on settings, time-current characteristics, and interlocks for a specified fault location and type.

TABLE I SEQUENCE OF OPERATION

ID	TIME (ms)	IF (kA)	T1 (ms)	CONDITION
PCC PN-15F2_R	400	31.995	400	Phase - OC1 - 50
PCC PN-15F2_CB	430		30	Tripped by PCC PN-15F2_R Phase - OC1 - 50
6.6KV_SB_PN-13_R	631	2.048	631	Phase - OC1 - 51
6.6kV_SB_PN-13_CB	691		60	Tripped by 6.6KV_SB_PN-13_R Phase-OC1-51
6.6KV_SB_PN-15_R	1201	2.048	1201	Phase - OC1 - 51
6.6kV_SB_PN-15_CB	1261		60	Tripped by 6.6KV_SB_PN-15_R Phase-OC1-51

V. CONCLUSION

As par study of the Power system analysis and relay coordination, First we see about load flow, in these cement plant have 1700kW motor, and this motor have not capacitor bank so that's reason reactive power flow is an increase in the system, so we suggest a capacitor bank to improve power factor, reactive power compensation also improve the voltage profile of the system, secondly, we performed short circuit study, that study results show on a 0.415kV system a short circuit current is very high and it's Exceed the circuit breaker breaking capacity so we suggest, if not requited do not run transformer in parallel operation, if it's not possible to change the circuit breaker with help of short circuit current reference with results but it's too costly and last we suggest an increase impedance in the path of between transformer to PCC to limiting fault current that's why we recommended replacing bus duct with cable. And third the relay coordination part we suggest settings for adequate operation and the sequence of operation table shows the operating time for the operation, the purpose of the study is to achieve an efficient power system and its fulfilment

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