Short Circuit Analysis of an Industrial Distribution System

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Abstract—**The power system studies are required to evaluate the performance of the system at planning stage as well as running conditions. This paper presents short circuit analysis of an industrial electrical power distribution system in compliance to IEC 60909. Short-circuit studies can be performed at the planning and design stage in order to help finalize the system layout, determine voltage levels, protection equipments, switchgears, and cables size, transformers, grounding and earthing. The industrial distribution system is simulated on ETAP software and different fault study is performed.**

Keywords: **ETAP, IEC 60909, Short circuit analysis**

I.   Introduction

The industrial power system studies primarily consists of the techniques used to size and selection of equipment and predict or improve the performance of an existing or proposed power system under specified conditions. The power system optimization for industrial facilities can be achieved through the combination of several power studies [1]. Short circuit (SC) studies are one of the most important as compare to other fundamental power system studies. According to IEC 60909, short circuit is accidental or intentional conductive path between two or more conductive part forcing the electric potential difference between these conductive parts to be equal or close to zero.

Short circuit in a system creates high magnitude currents which is many times greater than load currents. The consequences of these Short circuit study determines fault current in system for various faults, three-phase, three phase-to-ground, line-to-line, double-line-to-ground and single-line-to-ground. All major sources of fault current should be represented in short circuit calculation model. The key short circuit current sources are utility/grid supply, synchronous machines (generators and motors), and induction motors [2].

The short circuit in the system cannot always be prevented; its effect can only be reduced by considering its consequences on the system at the time of planning and design stage [4]. The system components, transformers, cables, switchgears, protection equipments etc must be designed and selected to have

fault withstand capability to match system fault current rating [2-9].

The objectives of performing sort circuit study are:

- To prepare basis for the selection of the interrupting equipment and also to verify adequacy of existing interrupting equipment;
- To determine the system protective device settings;
- To coordinate protective devices
- To determine the effects of the fault currents on various system components during the time the fault persists;
- Conceptualization, design and refinement of system layout, neutral grounding, and substation grounding;
- To ascertain the minimum short-circuit current.

II.   System Description And Simulation

In order to determine actual performance of a power system, the proper mathematical models and accurate parameters of the study power network, the generator, exciter, and governor control systems of the cogeneration unit and loads have to be identified. The single line diagram (SLD) of ICP power distribution system is shown in Figure 1. The industrial cogeneration power distribution system is simulated on ETAP software.

To provide continuous power supply for critical loads and enhance overall efficiency of the plant, ICP has installed two 10MW steam based cogeneration units STG-1 and STG-2. Both generating units in study are represented by detailed model with transient and sub-transient circuits on both the direct and quadrate axes. The power is generated at 11kV and step-down to 6.6kV by generator transformers GT-301 and GT-302 and connected to Switchgear SG-301B.

To improve system reliability and power quality, the ICP has Grid connectivity with public power company (PPC) at two points. PPC power is available at 66 kV voltage level through utility ties UTG-1 and UTG-2. The motors above 160kW rating are connected to switchgear SG-401A and SG-401B at 6.6kV voltage level. The rated capacity of each generator is 10 MW and the total load connected is approximate 28.5 MW.

ETAP software is used for simulation and study of industrial system. ETAP short circuit Toolbar for IEC 60909 standard is shown in Figure 2. LG, LL, LLG, & 3-Phase Faults (IEC 60909) tab is used to perform line-to-ground, line-to-line, line-to-line-to-ground, and three-phase fault studies per IEC 60909 Standard. This study calculates initial symmetrical rms, peak and symmetrical breaking rms, and steady-state rms short-circuit currents at faulted buses.

3-Phase Faults - Transient Study (IEC 61363) tab is used to perform a 3-phase fault study per IEC 61363 Standard. This study calculates instantaneous values of actual short circuit current, DC offset, short circuit current envelope, AC component, and DC offset in percent for total short circuit current at faulted buses.
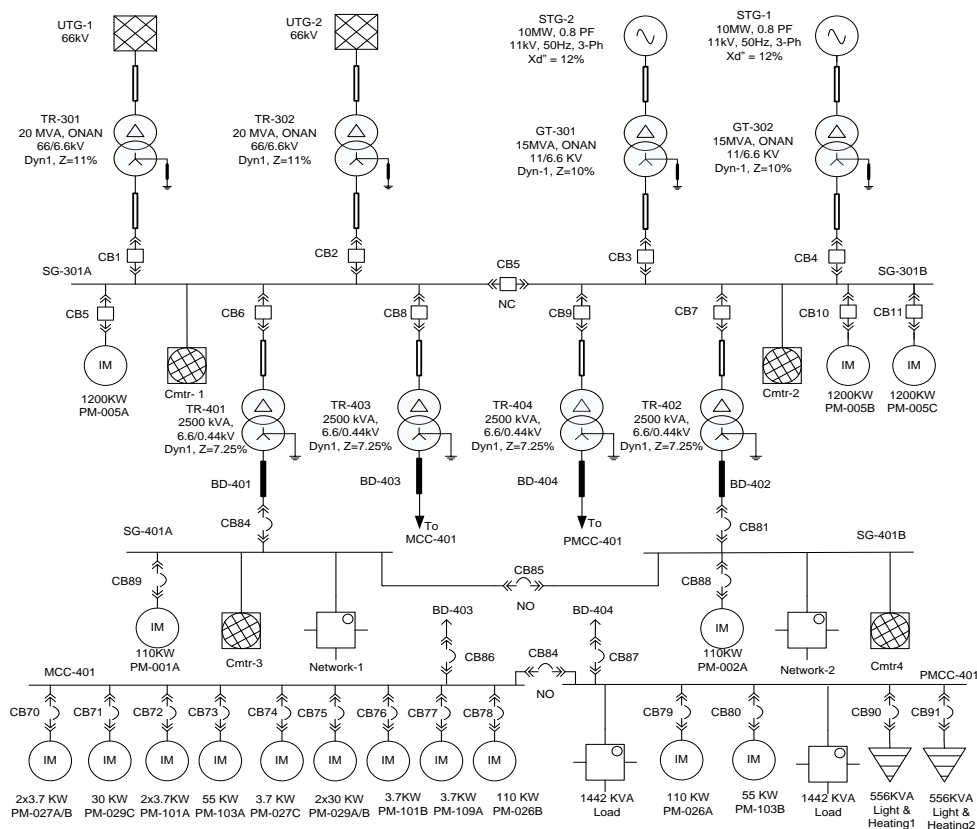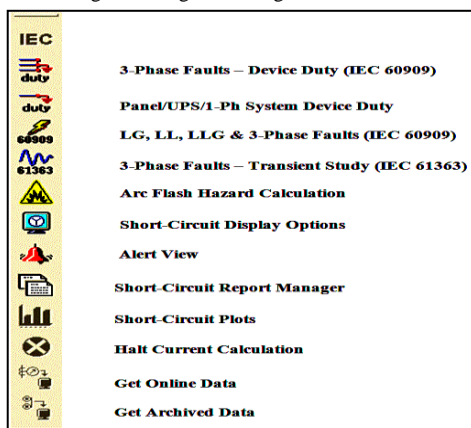

Figure.1 Single line diagram for the OTS

Figure 2 ETAP Short circuit toolbar

III.   Short Circuit Analysis

Industrial power systems are normally multi machine systems with many motors and possibly more than one generator, all interconnected through transformers, lines, and cables. The utility/grid usually modelled as a constant voltage source behind equivalent impedance. The ac component of fault current supplied by utility is constant as shown in figure 3 because of the higher impedances of the cables, lines and transformers which are fairly constant and high magnitude. The fault current supplied by synchronous machine and induction motor decays with time until a study-state value is reached. The AC component of short circuit current supplied by the synchronous generator is shown in Figure 3.
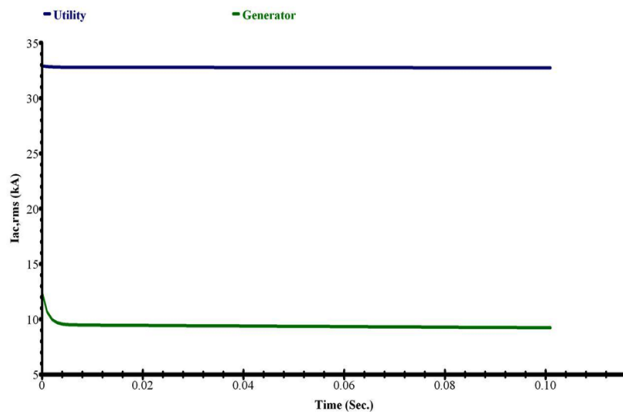

Figure. 3 AC component of fault current

In short circuit studies, two types of short circuit currents, which differ in their magnitude, are must be calculated:

- The maximum short circuit current i_p which determine the capacity or rating of electrical equipments; and
- The minimum short circuit current I_K which can be a basis for the selection of fuses and setting of protective devices.

The results of the short circuit analysis for considered industrial power system are given in TABLE 1.

The short circuit study is performed for 3-phase fault, line-to-ground (L-G) fault, line-to-line (L-L) fault and line-to-line-to-ground (L-L-G) fault and I''$_K$ (initial AC symmetrical SC current), i_p (peak SC current) and I_K (study state SC current) is determined.

The $I_K^{''}$ is the rms value of initial AC symmetrical short circuit current calculated by equation (1)

$$I_K^{''} = \frac{c.U_n}{\sqrt{3}\,Z_K} \qquad (1)$$

Where

Z_k = equivalent impedance at the fault location.

c = Voltage factor

The c factor or voltage factor is the ratio of equivalent voltage to nominal voltage and required to account for variation due to time & place, transformer taps, static load & capacitance, generator & motor subtransient behaviour. The peak current i_p can be calculated by equation (2) where k is a function of system X/R ratio at the fault location.

$$i_p = \sqrt{2} \times k \times I_K^{''} \qquad (2)$$

The X/R depends on the method selected for calculation as shown in ETAP short circuit study toolbar fig 3. The Method A for uniform R/X ratio, Method B is used for Meshed Network and Method C is used for Non Meshed Network.
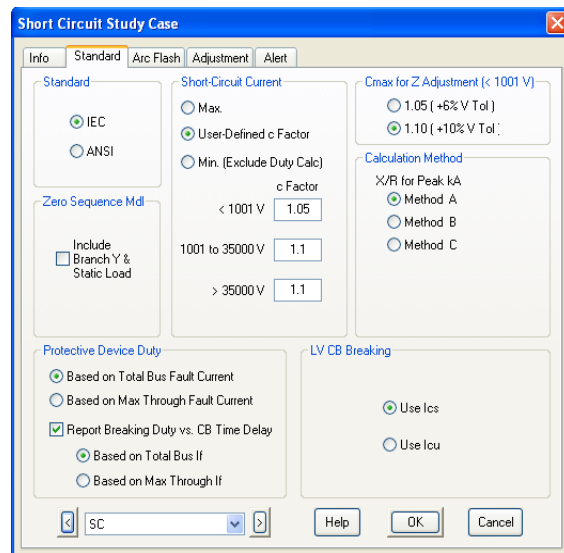

Figure.3 ETAP short circuit study case toolbar

TABLE.1 SHORT CIRCUIT ANALYSIS RESULT

Bus ID	3-Phase Fault			L-G Fault			L-L Fault			L-L-G Fault		
	I"$_K$	i$_p$	I$_K$	I"$_K$	i$_p$	I$_K$	I"$_K$	i$_p$	I$_K$	I"$_K$	i$_p$	I$_K$
SG-301A	58.5	148.1	41.0	43.7	110.5	43.7	50.9	128.9	50.9	53.9	136.3	53.9
SG-301B	58.5	148.1	41.0	43.7	110.5	43.7	50.9	128.9	50.9	53.9	136.3	53.9
SG-401A	48.0	117.5	45.8	48.4	118.5	48.4	41.5	101.5	41.5	48.4	118.5	48.4
SG-401B	46.7	115.0	45.8	47.6	117.2	47.6	40.4	99.6	40.4	47.3	116.4	47.3
PMCC-401	46.4	115.0	45.8	47.4	117.5	47.4	40.2	99.6	40.2	46.9	116.4	46.9
MCC-401	60.0	139.1	45.8	55.5	128.7	55.5	51.1	118.5	51.1	59.2	137.2	59.2

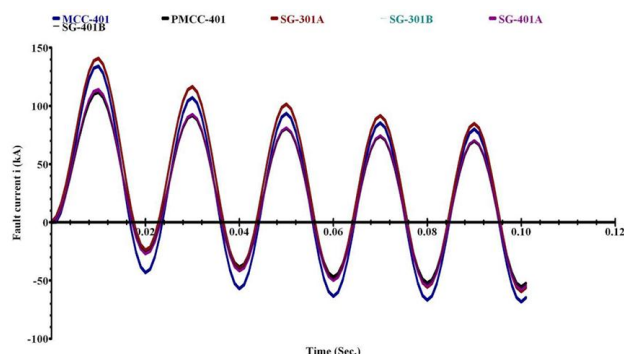The total fault current at different system busses is shown in Figure 4.

Figure 4 Total fault current at different buses

IV. Conclusion

The Simulation and short circuit study of an industrial electrical power distribution system is performed on ETAP software. The short circuit studies are performed by considering different types of faults in system and and I''_K (initial AC symmetrical SC current), i_p (peak SC current) and I_K (study state SC current) is determined. The results of short circuit studies are useful in order to determine system configuration, system voltage levels, protection equipments, switchgears, and cables size, transformers, grounding and earthing.

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