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Short-circuit analysis of Industrial plant

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Abstract -*Short circuit analysis is one of the power system analysis method and which is performed to size the power system and protective devices as well as find electrical parameters for power system protection design. Additionally, it is also performed at regular interval of time for troubleshooting as well as decides setting of relays with considering load expansions. In industrial plant, it is performed during planning stage as well as when remarkable change occurs in load as well as generation. . In this paper, the short circui analysis of 6.6 kV industrial plants is presented using Electrical Transient Analysis Program -7.5.5(ETAP). The plant is supplied by two in plant generators (2*16.5 MW Existing and 11.8 MW-newly installed). The external grid supply is used for black start of TG's. Existing load is raised from 17.5 MW to 24 MW, after expansion. So this analysis is performed to check sizing of different protective devices with generation surplus and operating philosophy selection.G2+G3 configuration short circuit current is recommended for relay coordination setting and for device duty varifications.*

Keywords- *Short circuit Analysis, ETAP, ANSI method, IEC method, Classical Method.*

I. INTRODUCTION

Engineers find short-circuit current by performing short circuit analysis to ensure short circuit rating of circuit devices as well as for relay coordination. If circuit device rating isn't adequate or if mis-coordination is occurred, remarkable damage is occurred to power system with long duration of power failure. Therefore, exact value of short-circuit is needed for power system design as well as to design properly coordinated protection systems. So it does finally facilitate stable and reliable power system operation. Different values of fault currents are found by short circuit analysis at different time period after fault inceptions and at different power system points [1].

The short circuit analysis is perform to find the value of fault current at different node and different voltage level as well as different time interval after the fault inceptions. These current are then used for protective and power system equipment selection. Furthermore, minimum value of short circuit current is used for setting relay at different voltage level [2][3].

Maximum and minimum values of 3 phase fault current are found at 10 ms and 60 ms after inception of fault. Minimum value of fault current is utilized for relay setting whereas maximum value of fault current is utilized to determine making capacity of protective devices such as circuit breakers. Additionally, minimum value of earth fault current is also needed to find for earth fault protection design. Protective device pricing depends upon making and breaking capacity of devices and there are huge variations in price with small variation in ratings. Therefore, exact value of fault current helps us to select appropriate and cost effective devices and reduce overall purchase cost.

Short circuit analysis is performed for two purposes [6]
1, Device duty calculations

- To find the maximum symmetrical fault currents to compare with low voltage equipment short circuit ratings and medium voltage equipment interrupting ratings.
- To find the maximum crest fault current to compare with Low Voltage equipment crest ratings and medium voltage equipment close and latching ratings.

2, Relay coordination Calculation

II. ASSUMPTION AND MODELING

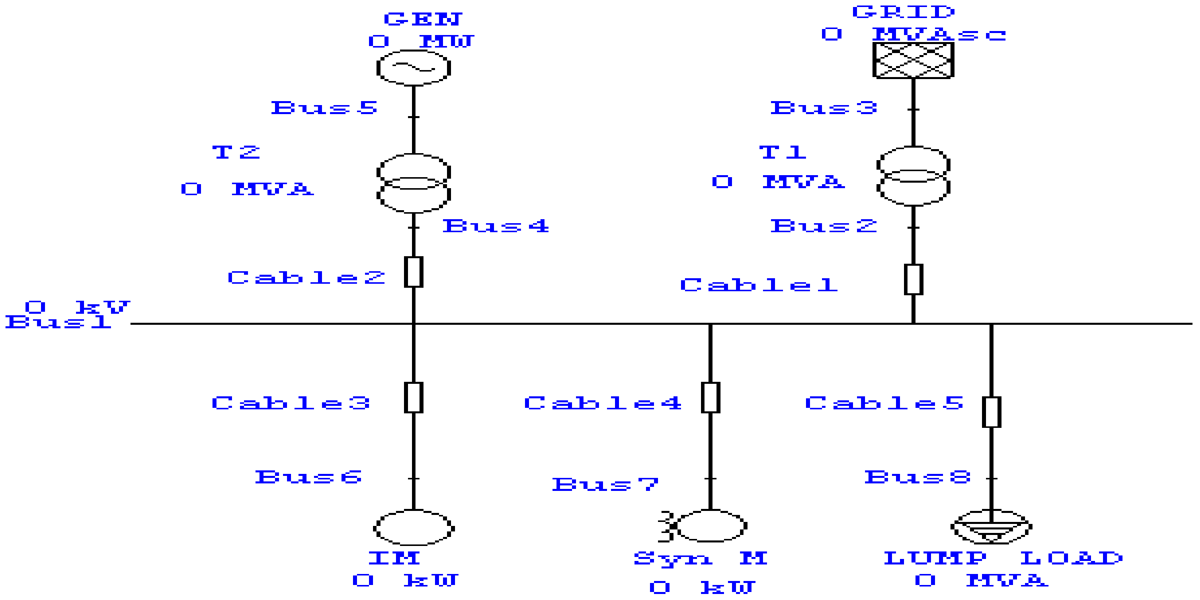
Following assumptions are made for short circuit analysis [5];Generators and synchronous motor are modeled by their different reactance such as sub transient, transient, steady state, negative, and zero sequence reactance.

1. Induction machines are modeled by their stand-still reactance.
2. Transformer impedance is also modeled as a positive, negative and zero sequence reactance.
3. It is considered that positive and negative sequence impedance is similar.
4. Resistance of all equipment and power system component are neglected.
5. The H.T.motors as well as higher power rated motors are considered in IEC-60909 calculations and other remaining

6. motors have negligible contribution to the short circuit current and have been considered as static loads. To following IEC-60909 standard, fault current contribution given by all motors are taken in to consideration to finding the maximum value of short circuit current because they operate as induction generators after fault incepting and during the first cycles due to its inertia.

III. SHORT CIRCUIT CURRENT CALCULATION

Short circuit current contributions of different devices are found as under [7][8].



1. Equation for generator, synchronous motor, power grid, transformer.

X (per-unit X at base MVA)
= {(base MVA/machine base MVA) *(per-unit X at machine MVA)}

2. Cable

PU X= {chosen base MVA/ (machine base Kv) ^{2}}* X (ohm).

3. Motor

PU X= {chosen base MVA*P.F/machine base MW} * X (actual).u

4. For generator contribution.

XT=Xg+Xt+Xc

5. For GRID contribution.

XT=XG+Xt+Xc

6. For MOTOR contribution.

XT=XM+Xc

7. Total Fault contribution; (I) = base MVA/Total PU X*1.735* kV.

Total fault level at bus=summation of individual fault contribution of all elements connected to bus. For device duty calculation Xd'', X (1) use in calculation. For relay coordination phase fault Xd', X (1) use & X (0) use in ground fault current calculation.

8. Transformer or generator with NGR or NGT

   Restricted value of earth fault current is; I=kV/√3*R

9. Transformer or generator with SOLID Grounding

   Zero sequence reactance taken in to consideration if given, otherwise it is assumed that zero sequence reactance similar to positive sequenced reactance.

   PU X0= X0*Base MVA/machine base MVA.

   Fault contribution (I) = base MVA/ PU X0*1.735* Kv

IV. SHORT CIRCUIT ANALYSIS METHOD

There are three methods are used for software based short circuit calculation [6][9][10]

1. Classical method
2. ANSI (American National Standards Institute) method
3. IEC (International Electro technical Commission) method

4.1 Classical Method

To find different values of short circuit current, networks of sub transient, transient reactance and steady state reactance are formed and there after using different theorem such as thevenin theorem and ohms law, networks are reduced and find short circuit current. To find the accurate value of making and breaking current, two different impendence networks are found using sub transient and transient reactance at 0 to 1 cycle and 3 to 5 cycle after fault inceptions. This is one of the easy methods to find short circuit current but it is cumbersome in hand calculation and useful for small number of buses.

4.2 ANSI (American National Standards Institute) Method

This method is based on U.S standards and use short circuit current calculation in low and medium high voltage. It's required less parameter modeling compare to IEC method and complexity is also less. Here, low voltage impedance network, low, medium and high voltage momentary and interrupting network form for analysis. Calculation process is expressed in next sections.

4.3 IEC (International Electro technical Commission) Method

This method is based on European standard and it is preferred for high voltage short circuit current calculations. It more accurate compare to ANSI method and detailed modeling is required. It is used to find different values of short circuit current such as instantaneous value of peak short circuit current, Decaying dc component of short circuit current, symmetrical rms short circuit breaking current, Asymmetrical rms short circuit breaking current and symmetrical rms steady-state shortcircuit current.

V. CALCULATION PROCEDURE

5.1 Momentary short circuit current calculation

Momentary short circuit current at the ½ cycle represent highest or maximum value of short-circuit current before its AC and DC components decay toward the steady-state value. Although the highest or maximum short-circuit current actually occurs slightly before the ½ cycle in reality, ½ cycle network use in calculation [11].

5.1.1 Calculate symmetrical rms value of momentary short-circuit current using the following formula [11].

I mom,rms,symm = Vpre-fault / √3*Zeq

Where, Zeq is the total impedance at the faulted bus of the half cycle network.

5.1.2 Calculate rms value of momentary asymmetrical short-circuit current using following formula [11].

I mom,rms,asymm = MFm I mom,rms,symm

Where MFm is momentary multiplying factor, calculated from

MFm = √ 1+2exp (-2Π/X/R)

5.1.3 Calculate Peak value of momentary short-circuits current using the following formula [11].

I mom,peak = MFp I mom,rms,symm

Where MFp is peak multiplying factor, calculated from

$MFp = \sqrt{2}\,[1+\exp(-\Pi/X/R)]$

In both equations MFm and MFp calculation, X/R is the ratio of X to R at the fault location obtained from separate X and R network at ½ cycle. The value of fault current calculated by this method can be used for following purposes

- Check the closing and latching capacity of high voltage circuit breaker
- Check the bus bracing capacity
- Adjust relay instantaneous setting
- Check interrupting capacity of fuse and low voltage circuit breakers

5.2 Interrupting short-circuit current calculation (HVCB)

5.2.1 Calculate symmetrical rms value of the interrupting short circuit current for using following formula [11].

$I_{int,rms,symm} = V_{pre\text{-}fault} / \sqrt{3}*Z_{eq}$

Where, Zeq is the total impedance of the faulted bus of e interrupting networks.

5.2.2 Calculate short-circuit current contribution to the faulted point from all other buses [11].
5.2.3 if the contribution is from a remote bus, symmetrical value corrected by the factor of MFr calculated from

$MFr=\sqrt{1+2\exp[(-4\Pi/x/r)\, t]}$

t is the contact separation time in the circuit breaker in cycle [11].

5.2.4 If the contribution from local generator, symmetrical value is corrected by factor of MF1.which are obtained from ANSI/IEEE C37.010 [11].

5.2.5 Calculate total remote contribution and local contribution, and thus NACD ratio [11].

$NADC = I_{remote} / I_{total}$

$I_{total}= I_{remote}+ I_{local}$

NACD=0, if all contribution local.
NACD=1, if all contribution remote.

5.2.6 Determine the actual multiplying factor (AMFi) from NACD ratio and calculate the adjusted rms value of interrupting short circuit current using following formula [11].

$I_{int,rms,adj}= AMFi*I_{int,rms,symm}$

Where

$AMFi=MF1+NACD\,(MFr-MF1)$

5.2.7 For symmetrical rated breaker, the adjusted rms value of interrupting short-circuit current is calculated using following formula [11].

$I_{int,rms,adj}= AMFi*I_{int,rms,symm} / S$

Where the correction factor S reflects an inherent capacity of A.C high voltage CB, which are rated on symmetrical current basis.

5.3 Interrupting short circuit current calculation (LVCB)

Due to instantaneous action of low voltage circuit breaker at maximum short-circuits value the ½ cycle network use for calculating interrupting short-circuits current [11].

5.3.1 Calculate symmetrical rms value of the interrupting short circuit current for using following formula [11].

$I_{int,rms,symm} = V_{pre\text{-}fault} / \sqrt{3}*Z_{eq}$

Where, Zeq is the total impedance at the fault node of the momentary network.

5.3.2 Calculate the adjusted asymmetrical rms value of interrupting short-circuit current using following formula [11].

I int, rms, adj= MFi*I int, rms, symm

Where, MF =√2*{1+exp (-Π/x/r)}/√2*{1+exp (Π/x/r) test}, when based on peak current option selected in the short circuit study case.

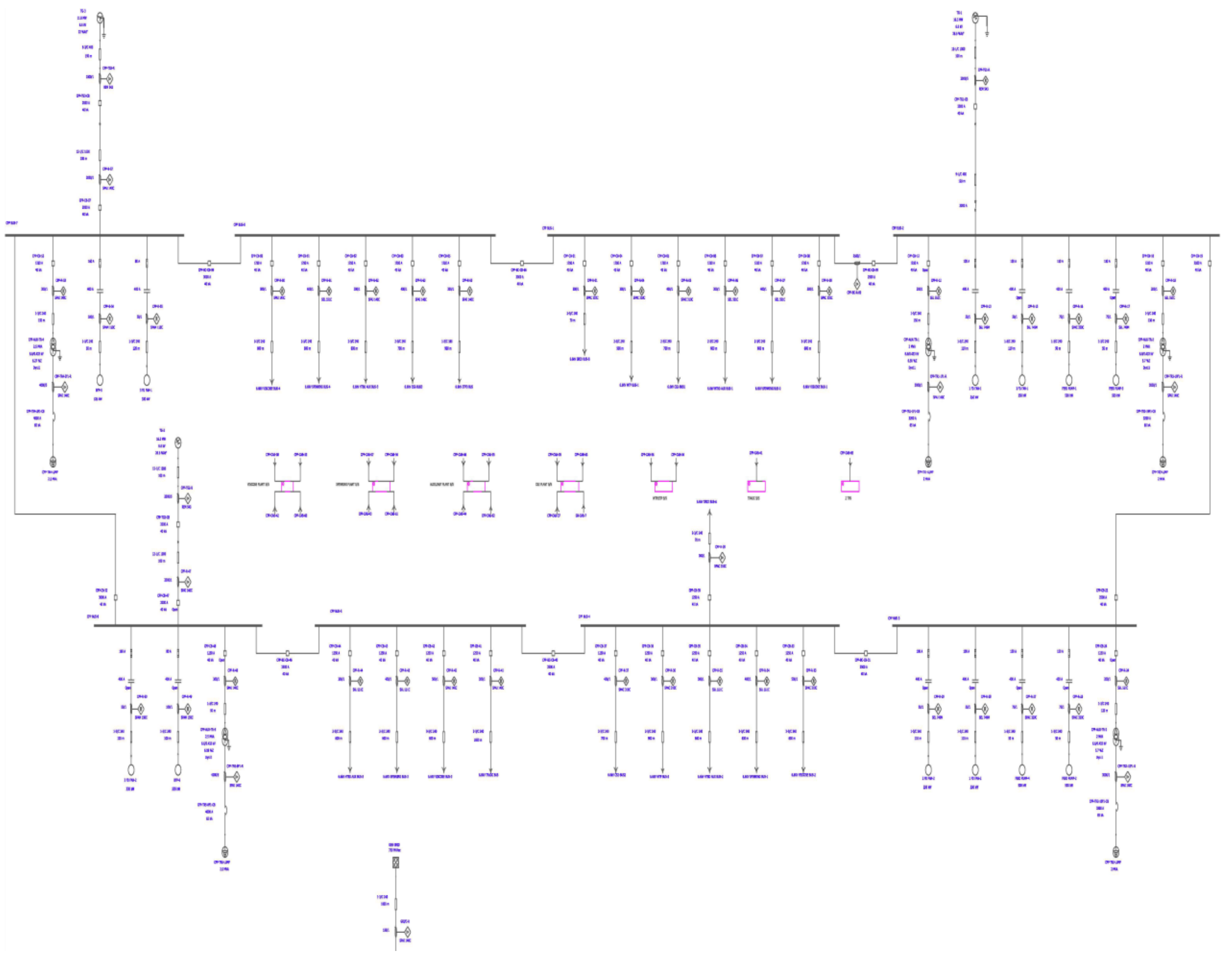
MF=√1+2exp (-2Π/x/r)/ √1+2exp (-2Π/x/rtest), when based on asymmetrical current option selected in the short circuit study case.

VI. RESULT ANALYSIS

2.6.1 Data

Following data are required to perform simulations [9];

1. Single-line diagram of industrial plant.
2. All data of transformer.
3. All data related to motor load.
4. All data of power factor improvement devices.
5. All data related to generators.
6. All data related to Bus bar, Panel, Cable, Circuit breaker, Isolators.
7. All data related to interconnected resource.



2.6.2 Results

Birla cellulosic is 175 bus system with inplant steam based generation (by three generator 2*15.6MW &1*11.8 MW, G1/G2=15.6 MW, G3=11.8 MW) with 22kV Grid support for black start and emergency supply provide to CS2 (carbon disulphide).Total 175 branch of the plant form by 37 transformer (distributions & furnace), 74 line/cable, 64 Tie circuit. Short circuit analysis conducted using ETAP-7.5.5 & selecting IEC-60909 method.
Short circuit analysis conducted only considering in plant generation with alternate generator combination G1+G2, G2+G3, G3+G1. All generators in parallel configuration are also presented to check maximum fault level.

(1) Device duty calculation results for G1+G2+G3 Configuration

- The short circuit level on the generator bus (CPP-1 TO CPP-7) with the three generators in parallel and feeding the entire Plant load is 25.056 kA. The bus rated fault level is 40kA for 1 second and thus the short circuit capacity of the bus is adequate. CPP-1(CB CP3) Breaker and 22 kV grid breaker have a breaking capacity is 25 kA for 1 second but maximum fault current at this buses are 20 kA and 19.64 kA. So no need to replace.
- Making capacity of all breakers at generator bus is 100kA & 125 kA. Peak current at generator bus with all generators in parallel is 71.52kA. Thus it is adequate.
- At Some circuit breaker, value of Idc (D.C.Component of fault current) is greater than calculated value but it is not objectionable because most of breaker operated after 8 to 9 cycle after the fault occur and D.C.Component of fault current die-out in 5 to 7 cycle. Also in all case asymmetrical fault current below device calculate value.
- All LT Breaker (release) rated with short circuit withstand current of 62kA and 42 kA for 1sec and calculated values are 53 kA and 39 kA.
-

(2) Device duty calculation results for G1+G2 Configuration

- The short circuit level on the generator bus (CPP-1 TO CPP-7) with G1 in parallel with G2 is 16.675 kA. All breaker rated 40kA for 1 second except CPP-1(CB CP3) Breaker. This is rated 25 kA for 1 second and fault current is 13.78 kA.
- Making capacity of all breakers at generator bus is 100kA & 125 kA. Peak current at generator bus with all generators in parallel is 47.29 kA. Thus it is adequate.
- At some breaker Idc is greater than device duty but it is neglected due to above reason
- All L.T.Breaker release rated with short circuit withstand current 62kA and 42 kA for 1sec and calculated value is 50 kA and 37 kA.

(3) Device duty calculation results for G2+G3 Configuration

- The short circuit level on the generator bus (CPP-1 TO CPP-7) with G2 in parallel with G3 is 15.324kA .all breaker rated 40kA for 1 second except CPP-1(CB CP3) Breaker. This is rated 25 kA for 1 second and fault current is 12.55 kA.
- Making capacity of all breakers at generator bus is 100kA & 125 kA. Peak current at generator bus with all generators in parallel is 44.39kA. Thus it is adequate.
- At some breaker Idc is greater than device duty but it is neglected due to above reason
- All LT Breaker (release) rated with short circuit withstand current 62kA and 42kA for 1sec and calculated value is 49.32 kA and 36.8 kA.

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Location:	BIRLA CELLULOSIC LTD, KOSAMBA	7.5.0C		Date:	02-01-2012
Contract:	ELCON ENGINEERS PVT. LTD			SN:	ELCONENGPL
Engineer:	ASHOK PARMAR	Study Case:	SC-DD	Revision:	Base
Filename:	BIRLA CELLULOSIC			Config.:	G2+G3(ON)

Short-Circuit Summary Report

3-Phase Fault Currents

Bus		Device		Device Capacity (kA)				Short-Circuit Current (kA)					
ID	kV	ID	Type	Making Peak	Ib sym	Ib asym	Idc	I"k	ip	Ib sym	Ib asym	Idc	Ik
6.6KV CS2 BUS-1	6.600	6.6KV CS2 BUS-1	SwitchGear	40.000				13.132	26.540				12.048
	6.600	CB CS10	CB	80.000	31.500	32.278	7.044	13.132	26.540	11.256	11.256	0.018	
	6.600	FCS-9	Fuse		120.000	159.693		13.132	26.540	12.583	14.565	7.612	
	6.600	FCS-16	Fuse		120.000	159.693		13.132	26.540	12.583	14.565	7.612	
	6.600	FCS-15	Fuse		120.000	159.693		13.132	26.540	12.583	14.565	7.612	
	6.600	FCS-14	Fuse		120.000	159.693		13.132	26.540	12.583	14.565	7.612	
	6.600	FCS-13	Fuse		120.000	159.693		13.132	26.540	12.583	14.565	7.612	
	6.600	FCS-12	Fuse		120.000	159.693		13.132	26.540	12.583	14.565	7.612	
6.6KV CS2 BUS-2	6.600	6.6KV CS2 BUS-2	Bus					11.013	20.063				10.217
	6.600	CB CS7	CB	80.000	31.500	32.278	7.044	11.013	20.063	9.992	9.992	0.000	

(4) Device duty calculation results for G3+G1 Configuration

- The short circuit level on the generator bus (CPP-1 TO CPP-7) with G2 in parallel with G3 is 15.14 kA .all breaker rated 40kA for 1 second except CPP-1(CB CP3) Breaker. This is rated 25 kA for 1 second and fault current is 12.33 kA.
- Making capacity of all breakers at generator bus is 100kA & 125 kA. Peak current at generator bus with all generators in parallel is 43.39 kA. Thus it is adequate.
- At some breaker Idc is greater than device duty but it is neglected due to above reason
- All LT Breaker (release) rated with short circuit withstand current 62 kA and 42 kA for 1sec and calculated value is 49.12 kA and 36.68 kA.

(5) Relay coordination results

- Minimum value of fault current for G1+G2 configuration is 15.62 kA for phase fault and 200A for ground fault
- Minimum value of fault current for G2+G3 configuration is 14.52 kA for phase fault and 200A for ground fault
- Minimum value of fault current for G2+G3 configuration is 14.80 kA for phase fault and 200A for ground fault

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Contract: ELCON ENGINEERS PVT. LTD			SN:	ELCONENGPL
Engineer: ASHOK PARMAR			Revision:	Base
Filename: BIRLA CELLULOSIC	Study Case:	SC-RC	Config.:	G1+G2(ON)

Short-Circuit Summary Report

3-Phase, LG, LL, LLG Fault Currents

Bus		3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
6.6KV CS2 BUS-1	6.600	12.303	25.178	11.317	0.100	0.204	0.100	0.100	10.614	21.720	10.614	10.614	10.638	21.769	10.638	10.638
6.6KV CS2 BUS-2	6.600	10.330	19.103	9.601	0.100	0.184	0.100	0.100	8.913	16.483	8.913	8.913	8.936	16.526	8.936	8.936
6.6KV CS2 BUS-3	6.600	12.303	25.178	11.317	0.100	0.204	0.100	0.100	10.614	21.720	10.614	10.614	10.638	21.769	10.638	10.638
6.6KV GRID BUS-A	6.600	4.319	10.739	4.319	0.248	0.617	0.248	0.248	3.741	9.300	3.741	3.741	3.803	9.454	3.803	3.803
6.6KV GRID BUS-B	6.600	4.315	10.705	4.315	0.248	0.616	0.248	0.248	3.737	9.271	3.737	3.737	3.798	9.424	3.798	3.798
6.6KV SPINNING BUS-1	6.600	13.789	31.169	12.470	0.100	0.226	0.100	0.100	11.881	26.858	11.881	11.881	11.906	26.914	11.906	11.906
6.6KV SPINNING BUS-2	6.600	13.789	31.169	12.470	0.100	0.226	0.100	0.100	11.881	26.858	11.881	11.881	11.906	26.914	11.906	11.906
6.6KV SPINNING BUS-3	6.600	11.397	22.173	10.567	0.100	0.194	0.100	0.100	9.836	19.136	9.836	9.836	9.860	19.182	9.860	9.860
6.6KV SPINNING BUS-4	6.600	11.397	22.173	10.567	0.100	0.194	0.100	0.100	9.836	19.136	9.836	9.836	9.860	19.182	9.860	9.860
6.6KV TRADC BUS	6.600	7.433	12.356	7.084	0.099	0.165	0.099	0.099	6.422	10.676	6.422	6.422	6.443	10.711	6.443	6.443
6.6KV VISCOSE BUS-1	6.600	14.348	34.178	12.957	0.100	0.238	0.100	0.100	12.364	29.453	12.364	12.364	12.389	29.512	12.389	12.389
6.6KV VISCOSE BUS-2	6.600	11.922	23.999	10.922	0.100	0.201	0.100	0.100	10.279	20.692	10.279	10.279	10.303	20.740	10.303	10.303
6.6KV VISCOSE BUS-3	6.600	14.348	34.178	12.957	0.100	0.238	0.100	0.100	12.364	29.453	12.364	12.364	12.389	29.512	12.389	12.389
6.6KV VISCOSE BUS-4	6.600	14.306	33.304	12.931	0.100	0.233	0.100	0.100	12.329	28.702	12.329	12.329	12.354	28.739	12.354	12.354
6.6KV WTP BUS-1	6.600	10.534	18.858	9.863	0.100	0.178	0.100	0.100	9.097	16.284	9.097	9.097	9.119	16.324	9.119	9.119
6.6KV WTP BUS-2	6.600	10.534	18.858	9.863	0.100	0.178	0.100	0.100	9.097	16.284	9.097	9.097	9.119	16.324	9.119	9.119
22KV GRID BUS	22.000	19.614	53.412	19.614	18.286	49.796	18.286	18.286	16.986	46.256	16.986	16.986	22.866	62.268	22.866	22.866

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Contract:	ELCON ENGINEERS PVT. LTD		SN:	ELCONENGPL
Engineer:	ASHOK PARMAR		Revision:	Base
Filename:	BIRLA CELLULOSIC	Study Case: SC-RC	Config.:	G2+G3(ON)

Short-Circuit Summary Report

3-Phase, LG, LL, LLG Fault Currents

Bus		3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
6.6KV CS2 BUS-1	6.600	11.622	24.067	10.596	0.100	0.207	0.100	0.100	9.547	19.769	9.547	9.547	9.572	19.822	9.572	9.572
6.6KV CS2 BUS-2	6.600	9.864	18.474	9.093	0.100	0.187	0.100	0.100	8.176	15.311	8.176	8.176	8.200	15.357	8.200	8.200
6.6KV CS2 BUS-3	6.600	11.622	24.067	10.596	0.100	0.207	0.100	0.100	9.547	19.769	9.547	9.547	9.572	19.822	9.572	9.572
6.6KV GRID BUS-A	6.600	4.319	10.739	4.319	0.248	0.617	0.248	0.248	3.741	9.300	3.741	3.741	3.803	9.454	3.803	3.803
6.6KV GRID BUS-B	6.600	4.315	10.705	4.315	0.248	0.616	0.248	0.248	3.737	9.271	3.737	3.737	3.798	9.424	3.798	3.798
6.6KV SPINNING BUS-1	6.600	12.931	29.484	11.588	0.100	0.228	0.100	0.100	10.548	24.052	10.548	10.548	10.574	24.112	10.574	10.574
6.6KV SPINNING BUS-2	6.600	12.931	29.484	11.588	0.100	0.228	0.100	0.100	10.548	24.052	10.548	10.548	10.574	24.112	10.574	10.574
6.6KV SPINNING BUS-3	6.600	10.817	21.312	9.944	0.100	0.196	0.100	0.100	8.923	17.580	8.923	8.923	8.948	17.629	8.948	8.948
6.6KV SPINNING BUS-4	6.600	10.817	21.312	9.944	0.100	0.196	0.100	0.100	8.923	17.580	8.923	8.923	8.948	17.629	8.948	8.948
6.6KV TRADC BUS	6.600	7.205	12.091	6.822	0.099	0.167	0.099	0.099	6.054	10.161	6.054	6.054	6.077	10.198	6.077	6.077
6.6KV VISCOSE BUS-1	6.600	13.414	32.139	12.004	0.100	0.239	0.100	0.100	10.918	26.158	10.918	10.918	10.944	26.221	10.944	10.944
6.6KV VISCOSE BUS-2	6.600	11.290	23.007	10.252	0.100	0.203	0.100	0.100	9.286	18.924	9.286	9.286	9.312	18.975	9.312	9.312
6.6KV VISCOSE BUS-3	6.600	13.414	32.139	12.004	0.100	0.239	0.100	0.100	10.918	26.158	10.918	10.918	10.944	26.221	10.944	10.944
6.6KV VISCOSE BUS-4	6.600	13.379	31.367	11.983	0.100	0.234	0.100	0.100	10.892	25.537	10.892	10.892	10.918	25.599	10.918	10.918
6.6KV WTP BUS-1	6.600	10.053	18.236	9.334	0.100	0.181	0.100	0.100	8.333	15.117	8.333	8.333	8.357	15.160	8.357	8.357
6.6KV WTP BUS-2	6.600	10.053	18.236	9.334	0.100	0.181	0.100	0.100	8.333	15.117	8.333	8.333	8.357	15.160	8.357	8.357
22KV GRID BUS	22.000	19.614	53.412	19.614	18.286	49.796	18.286	18.286	16.986	46.256	16.986	16.986	22.866	62.268	22.866	22.866

Project:	POWER SYSTEM STUDY AND RC.	ETAP	Page:	1
Location:	BIRLA CELLULOSIC LTD, KOSAMBA	7.5.0C	Date:	02-01-2012
Contract:	ELCON ENGINEERS PVT. LTD		SN:	ELCONENGPL
Engineer:	ASHOK PARMAR		Revision:	Base
Filename:	BIRLA CELLULOSIC	Study Case: SC-RC	Config.:	G3+G1(ON)

Short-Circuit Summary Report

3-Phase, LG, LL, LLG Fault Currents

Bus		3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
6.6KV CS2 BUS-1	6.600	11.802	24.358	10.786	0.100	0.206	0.100	0.100	9.721	20.063	9.721	9.721	9.746	20.115	9.746	9.746
6.6KV CS2 BUS-2	6.600	9.988	18.640	9.228	0.100	0.186	0.100	0.100	8.298	15.486	8.298	8.298	8.322	15.531	8.322	8.322
6.6KV CS2 BUS-3	6.600	11.802	24.358	10.786	0.100	0.206	0.100	0.100	9.721	20.063	9.721	9.721	9.746	20.115	9.746	9.746
6.6KV GRID BUS-A	6.600	4.319	10.739	4.319	0.248	0.617	0.248	0.248	3.741	9.300	3.741	3.741	3.803	9.454	3.803	3.803
6.6KV GRID BUS-B	6.600	4.315	10.705	4.315	0.248	0.616	0.248	0.248	3.737	9.271	3.737	3.737	3.798	9.424	3.798	3.798
6.6KV SPINNING BUS-1	6.600	13.155	29.922	11.819	0.100	0.227	0.100	0.100	10.763	24.481	10.763	10.763	10.789	24.540	10.789	10.789
6.6KV SPINNING BUS-2	6.600	13.155	29.922	11.819	0.100	0.227	0.100	0.100	10.763	24.481	10.763	10.763	10.789	24.540	10.789	10.789
6.6KV SPINNING BUS-3	6.600	10.970	21.538	10.108	0.100	0.196	0.100	0.100	9.073	17.813	9.073	9.073	9.098	17.862	9.098	9.098
6.6KV SPINNING BUS-4	6.600	10.970	21.538	10.108	0.100	0.196	0.100	0.100	9.073	17.813	9.073	9.073	9.098	17.862	9.098	9.098
6.6KV TRADC BUS	6.600	7.266	12.162	6.892	0.099	0.166	0.099	0.099	6.117	10.239	6.117	6.117	6.139	10.276	6.139	6.139
6.6KV VISCOSE BUS-1	6.600	13.658	32.667	12.253	0.100	0.239	0.100	0.100	11.149	26.667	11.149	11.149	11.176	26.730	11.176	11.176
6.6KV VISCOSE BUS-2	6.600	11.457	23.267	10.428	0.100	0.203	0.100	0.100	9.449	19.189	9.449	9.449	9.474	19.240	9.474	9.474
6.6KV VISCOSE BUS-3	6.600	13.658	32.667	12.253	0.100	0.239	0.100	0.100	11.149	26.667	11.149	11.149	11.176	26.730	11.176	11.176
6.6KV VISCOSE BUS-4	6.600	13.621	31.869	12.231	0.100	0.234	0.100	0.100	11.122	26.023	11.122	11.122	11.149	26.085	11.149	11.149
6.6KV WTP BUS-1	6.600	10.181	18.400	9.474	0.100	0.180	0.100	0.100	8.460	15.290	8.460	8.460	8.484	15.333	8.484	8.484
6.6KV WTP BUS-2	6.600	10.181	18.400	9.474	0.100	0.180	0.100	0.100	8.460	15.290	8.460	8.460	8.484	15.333	8.484	8.484
22KV GRID BUS	22.000	19.614	53.412	19.614	18.286	49.796	18.286	18.286	16.986	46.256	16.986	16.986	22.866	62.268	22.866	22.866

VII. CONCLUSION

Primary objective to make short circuit analysis is to find short circuit current for equipment sizing and relay coordination. IEC 60909 methods is used to find different values of short circuit current. It is found that minimum value of fault current for G2+G3 configuration is 14.52 kA for phase fault and 200A for ground fault. Relay coordination is done with minimum fault current because relay set at minimum current will be operated at any higher value, so coordination is done with configuration G2+G3.Device duty result is also found for suggested configuration and observed that there is no any need to upgrade or replace. Final recommendation are concluded from this analysis are; (1) The short circuit level on the generator bus with the three generators in parallel and feeding the entire Plant load is 25.056 kA. The bus rated fault level is 40kA for 1 second and thus the short circuit capacity of the bus is adequate. (2) The short circuit level with G1 in parallel with G2 is 16.675 kA. & G2 in parallel with G3 is 15.324kA. G3 in parallel with G1 is 15.143 kA.(3) Making capacity of all breakers at generator bus is 100kA. Peak current at generator bus with all generators in parallel is 71.52kA.G1 in parallel with G2 is 47.29 kA.G2 in parallel with G3 is 44.39kA. & G3 in parallel with G1 is 43.39 kA. Thus, it is adequate. (4) The short circuit study indicates that all the fault levels on the buses are adequate. (5) The maximum fault clearing time on the upstream generator breaker is 950ms. The maximum operating time for the outgoing feeder relay on the HVSB buses is 350 ms. (6) We recommend not operating any two transformers of any PCC on plant side in parallel with each other because for such a case, fault level exceeds the switchgear breaking capacity. (7) Minimum value of fault current for relay coordination G1 in parallel with G2 is 15.62 kA. G2 in parallel with G3 is 14.52kA & G3 in parallel with G1 is 14.08 kA. Thus it is adequate. Operating philosophy G2+G3 is adopted because it is provided minimum total loss and minimum fault current.

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