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Modelling & Simulation of Grid Connected Biomass Power System

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ABSTRACT: To fulfill requirement of electricity in rural India, it is necessary to search for renewable energy based on decentralized approach rather than traditional ways. While considering option from renewable energy sources for rural electrification, bio-energy technologies are being explored. This work is basically intended to study and analyze biomass power plant for electricity generation. This work deals with analysis of 6MW Biomass power plant as a case study. The power flow, short circuit and relative protective relay co-ordination studies can be effectively done by using SKM software. This study mainly focuses on power flow and short circuit analysis of grid connected 6MW biomass plant.

KEYWORDS: Biomass Power Plant, Power flow, Short Circuit, Distributed Generation.

I.INTRODUCTION

It has been observed that there are various challenges in traditional electricity generation, also while scrutinizing the generation performance during the current years and even the power utilities are facing the problem of fuel supply and its availability, consequence of transmission restraints results in loss of generation, improper schedules and high fuel cost etc. Therefore this opens up a gigantic prospective for development of power generation plants at distribution level systems and the need to search for renewable energy based options in a sustainable way to meet the demand of energy in rural area. It is also essential to use renewable energy sources, as they are environment friendly and abundantly available everywhere.

Biomass is a term used to describe matter produced by photosynthesis. In photosynthesis process, chlorophyll in plants captures the sun's energy and converts it into carbohydrate *i.e.* complex compounds composed of carbon, hydrogen and oxygen. When these carbohydrates are burned they release the sun's energy they contain. Biomass includes all water and land based vegetation and trees, forestry and agricultural residues, and certain types of industrial wastes. Different techniques are used to convert biomass material into heat energy such as direct combustion, gasification, pyrolysis and anaerobic digestion [1].

In category of naturally occurring sources, biomass takes more attention as it is available on large scale in rural part of India. Also lot of barren land is available which can be used for cultivation of different biomass materials used in biomass power plants. Electricity generation by using biomass in India is 4550.55 MW and 464 TWh globally in 2015 [2]. Use of biomass power plant as distributed generation partly overcomes the problem of transmission losses and congestion of the grid.

This paper focuses on the issues involved in the electricity generation by direct combustion technique of biomass materials. Modelling and simulation of 6 MW biomass power plant is carried out to identify different issues. SKM software is found more suitable to carry out this study and used for analysis purpose [3].

II. SYSTEM DESCRIPTION

A practical case study of a 6 MW biomass power plant, M/s Armstrong Energy Private Ltd, Nasik, Maharashtra, India has been selected to study load flow and short circuit analysis. The block diagram of system is shown in figure 1. A turbine-generator set of 6 MW is delivering power to main copper bus bar. By using transformer 1, voltage of 11kV is

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step up to 33kV and provides to ring main unit of samangaon substation through metering room. Also to satisfy plant requirement for its operation a separate line of 33kV is taken after vacuum circuit breaker panel 5. When a turbine-generator set is not delivering power or under maintenance work, then power required for internal operation of plant is taken from ring main unit through transformer 2 from grid. In case of any failure in transformer 1 or that path, a spare line is utilized to feed the load of plant. Also DG set is used as a backup.

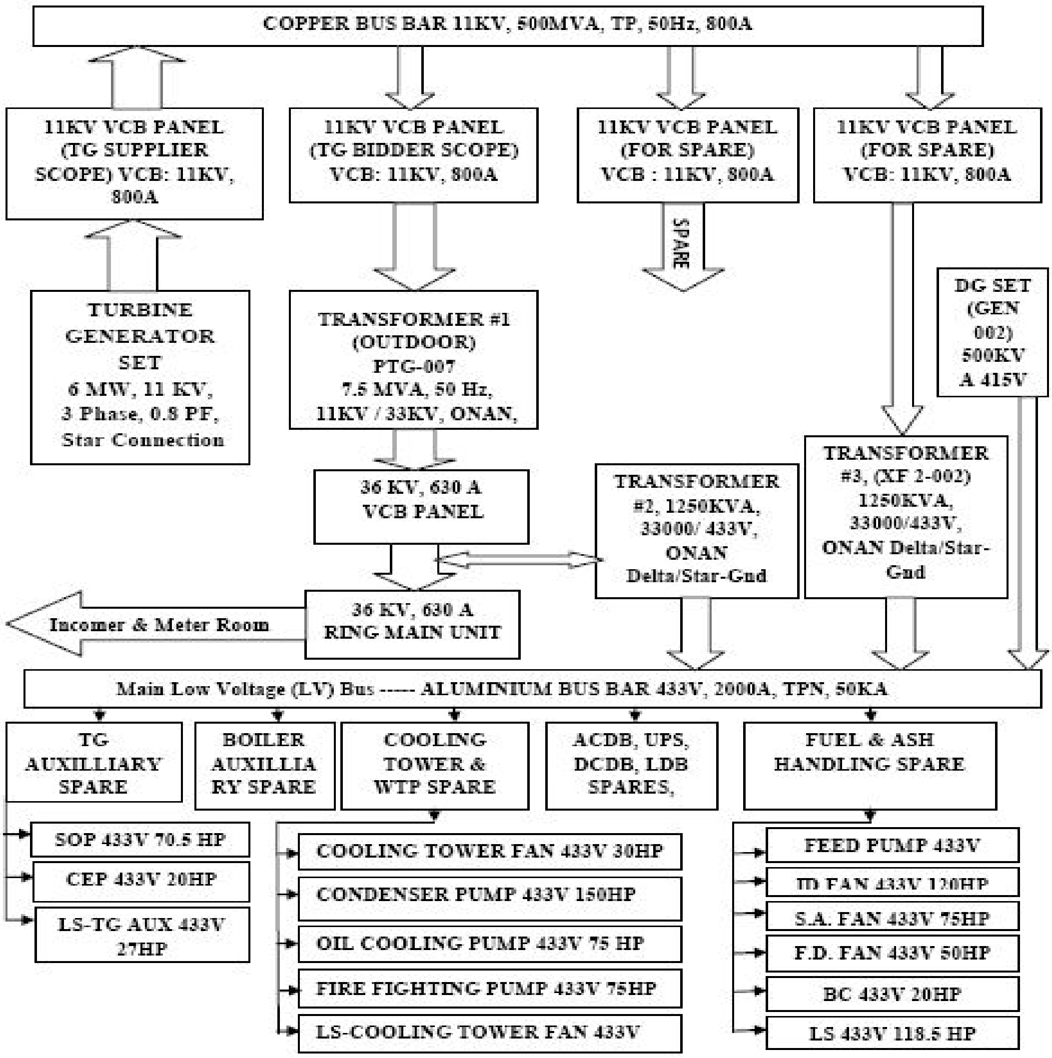

Fig.1: Block diagram of 6MW Biomass Power Plant (M/s. Armstrong Energy Private Limited)

A. Load Flow Analysis

In power system, assets are analyzed by observing load flow by maintaining reliability of supply. By using load flow analysis voltage sags are detected in this system [4,5]. The impact of uncertainty of supply to load and its power factor correction can also be studied with this load flow analysis [7,8,9].

The load flow analysis are used to find component or circuit loading, bus voltage profiles, real and reactive power flow, power system losses and proper transformer taps settings [10]. Certain parameters given below must be considered to evaluate the load flow before simulation such as generator, feeder, transformer and individual loads types, its size and configurations, power system topology and connections, utility connection (swing bus), run from tool bar - “Demand Load Study”.

Referring to figure 2 these steps are essential and have to be followed for the analysis of load flow in biomass power

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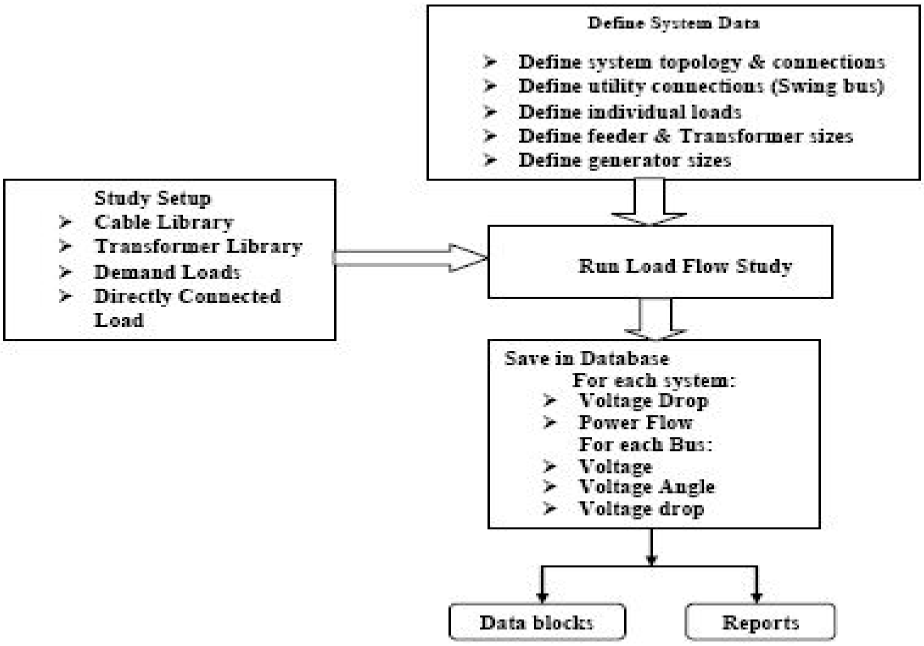

Fig. 2: Flow chart for Load flow studies

III.MODELLING & SIMULATION

The modeling of 6 MW biomass power plant referring the block diagram shown in figure 1 is done in SKM software and simulations are carried out. Actual system data of the biomass power plant at M/s Armstrong Energy Private Ltd, Nasik, Maharashtra, India is used for the simulations. The main system data is as follows:

- Generator data including its protective devices details and percentage impedance
- Feeder-wise line currents, line voltages, active power and reactive power
- Transformer data including HV and LV side voltages, currents and percentage impedance
- Transmission line data including length of the line, positive sequence resistance and reactance, zero sequence resistance and reactance
- Cables data including length of the cables and its types
- In Plant loads like cooling tower, fuel and ash handing, firefighting pumps

Using Newton Raphson method [6] given in SKM software load flow analysis is carried out as per the setting of parameters shown in table 1.

Table 1: Load flow and voltage drop analysis report

SKM Power Tools For Windows
All P.U. values are expressed on a 100 MVA base.
Load flow and voltage drop analysis report.
*************** Solution Comments **************
Solution Parameters
Branch voltage criteria : 3.00 %

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Bus voltage criteria	: 5.00 %
Utility impedance	: Yes
Transformer phase shift	: No
LTC Transformer	: No
Calculation method	: Newton Method
Load flow analysis based on connected loads.	
Load analysis includes all loads.	
<< Percent Voltage Drops are based on nominal design voltages >>	
Load Flow Study Settings	
Include Source Impedance	Yes
Solution Method	Exact (Iterative)
Generation Acceleration Factor	1.00
Load Acceleration Factor	1.00
Bus Voltage Drop %	5.00
Branch Voltage Drop %	3.00

Using SKM software Short circuit analysis is carried out as per the setting of parameters shown in table 2.

Table 2: Short circuit analysis results

Project: BIOMASS (Direct Combustion Based Technique using Agro Waste)	
DAPPER Unbalanced Fault Report	
Comprehensive Short Circuit Study Settings	
Three Phase Fault	Yes
Faulted Bus	All Buses
Single Line to Ground	Yes
Bus Voltage	First Bus From Fault
Line to Line Fault	No
Branch Currents	First Branch From Fault
Line to Line to Ground	No
Phase or Sequence	Report phase quantities
Motor Contribution	Yes
Fault Current Calculation	Initial Symmetrical RMS (with 1/2 Cycle Asym)
Transformer Tap	Yes
Asym Fault Current at Time	0.50 Cycles
Transformer Phase Shift	Yes

Single line diagram of 6 MW biomass power plant shown in figure 1 is developed and the actual data of selected power plant at Nasik is used in the modeling.

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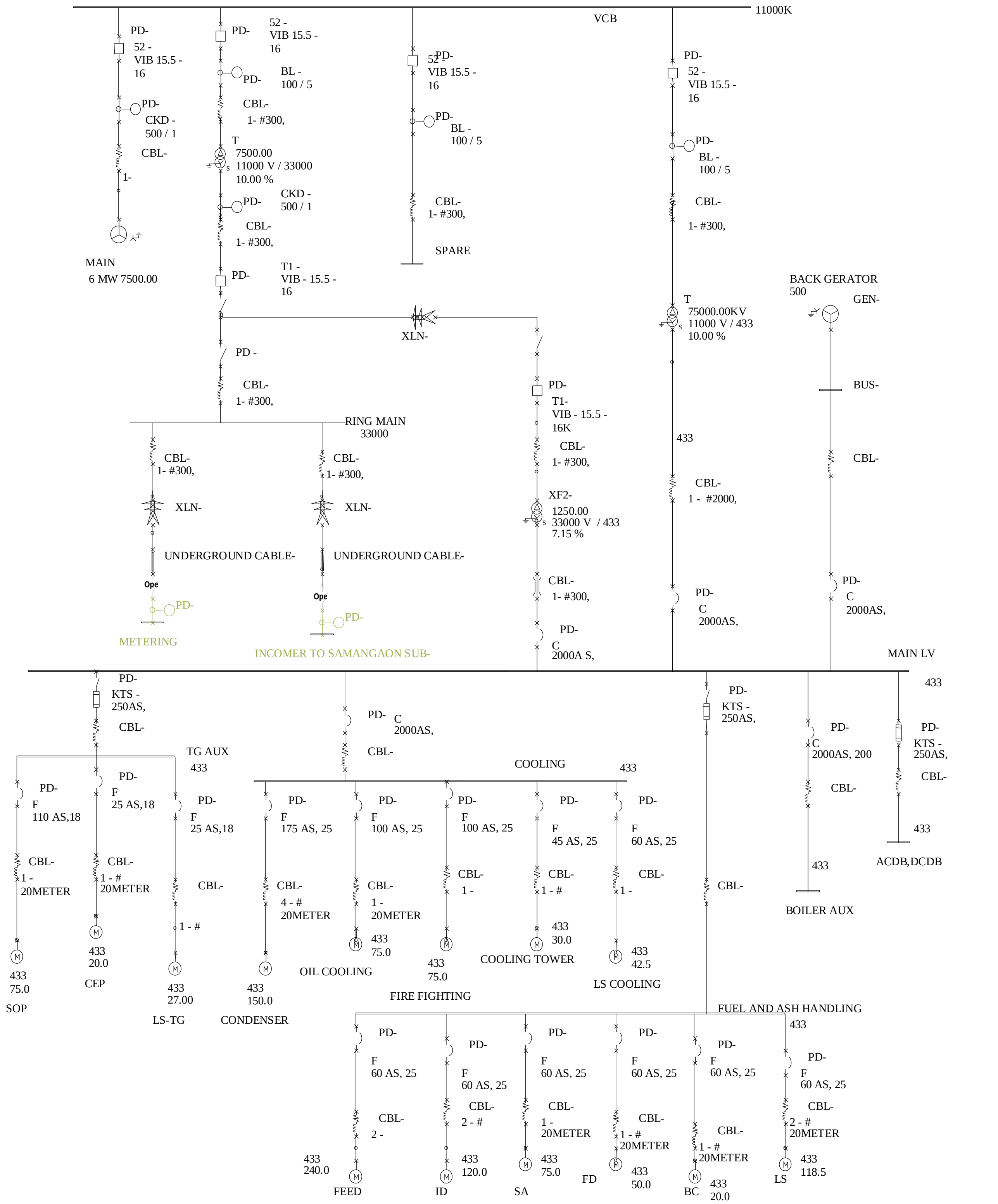

Fig.3: Single Line Diagram of 6MW Biomass Power Plant drawn in SKM Software

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IV. PERFORMANCE ANALYSIS

The performance of grid connected 6 MW biomass power plant based on direct combustion technique for load flow and short circuit analysis on various buses is simulated by using actual system data and results are discussed below.

A. Load Flow Analysis

The details of load flow and voltage drop analysis reports generated by SKM software with branch voltage and bus voltage criteria for buses (Table 3), swing generators (Table 4), and 2-winding transformers (Table 5) for biomass power plant are given below.

Table 3: Load flow and voltage drop analysis report for buses

Load Flow Summary Report – BUSES					
Bus Name	**Design Volts**	**LF Volts**	**Angle Degree**	**PU Volts**	**%VD**
ACDB, DCDB	433	405	-3.72	0.94	6.42
BOILER AUX SPARE	433	405	-3.72	0.94	6.42
BUS-0002	11,000	10,872	-0.81	0.99	1.16
BUS-0003	11,000	10,871	-0.81	0.99	1.17
BUS-0004	33,000	31,802	-2.25	0.96	3.63
BUS-0005	33,000	31,801	-2.25	0.96	3.63
BUS-0006	11,000	10,872	-0.81	0.99	1.17
BUS-0007	33,000	31,801	-2.25	0.96	3.63
BUS-0008	33,000	31,801	-2.25	0.96	3.63
BUS-0009	33,000	31,802	-2.25	0.96	3.63
BUS-0010	33,000	31,802	-2.25	0.96	3.63
BUS-0013	33,000	31,801	-2.25	0.96	3.63
BUS-0014	33,000	31,800	-2.25	0.96	3.64
BUS-0015	433	406	-3.75	0.94	6.21
BUS-0018	433	397	-2.99	0.92	8.31
BUS-0019	433	400	-3.25	0.92	7.65
BUS-0020	433	399	-3.18	0.92	7.82
BUS-0021	433	380	-2.46	0.88	12.22
BUS-0022	433	380	-2.46	0.88	12.22
BUS-0023	433	380	-2.46	0.88	12.22
BUS-0024	433	382	-2.63	0.88	11.77
BUS-0025	433	381	-2.49	0.88	12.09
BUS-0026	433	399	-3.26	0.92	7.89
BUS-0027	433	399	-3.26	0.92	7.89
BUS-0028	433	398	-3.17	0.92	8.02
BUS-0029	433	398	-3.12	0.92	8.07
BUS-0030	433	401	-3.43	0.93	7.36
BUS-0031	433	399	-3.27	0.92	7.88
BUS-0036	433	405	-3.72	0.94	6.37
BUS-0039	433	406	-3.68	0.94	6.18
COOLING TOWER	433	385	-2.96	0.89	11.04
FUEL & ASH HANDLING SPARE	433	403	-3.62	0.93	6.90
MAIN LV BUS	433	405	-3.72	0.94	6.42
RING MAIN UNIT	33,000	31,801	-2.25	0.96	3.63
SPARE BUS	11,000	10,872	-0.81	0.99	1.17
VCB PANEL	11,000	10,872	-0.81	0.99	1.17

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Table 4: Load flow and voltage drop analysis report for Swing generators

Load Flow Summary Report - Swing Generators						
Source	**V pu**	**Angle**	**KW**	**kvar**	**% VD**	**Utility Impedance**
GEN-0002	1.0	0.00	211.8	181.6	6.37	1.5+j30.0
MAIN GEN	1.0	0.00	737.6	521.8	1.16	0.13+j2.0

Table 5: Load flow and voltage drop analysis report for Two Winding Transformer

Load Flow Summary Report - 2-Winding Transformers							
From Bus / To Bus	**Component Name**	**% VD**	**kW Loss**	**kvar Loss**	**kVA Loss**	**LF Amps Rating %**	**PF**
BUS 0003	T1	2.46	724.9	523.4	894.1	47.5	0.81
BUS 0004			5.5	30.9	31.4	60.3	
BUS 0006	T3	5.01	12.6	-2.3	12.8	0.7	-0.98
BUS 0039			0.7	0.5	0.9	216.0	
BUS 0014	XF2-02	2.57	719.4	537.1	897.8	16.3	0.80
BUS 0015			5.8	32.8	33.3	62.1	

B. Short Circuit Study

Short circuit analysis determines the current and three phase voltage present in power system during single line to ground fault which are shown in table 5.

Table 5: Short circuit analysis results

Fault Bus Name	**3-ph Voltage**	**SLG Amp**	**3-ph Asymmetric**	
			Amps	**3 Cycles**
ACDB,DCDB	433	26228	30018	28674
BOILER AUX SPA	433	27296	32891	30552
BUS-0003	11000	0	4181	2922
BUS-0009	33000	1064	841	825
BUS-0010	33000	1064	841	825
BUS-0011	33000	857	767	747
BUS-0012	33000	857	767	747
BUS-0014	33000	1066	842	826
BUS-0016	33000	1064	841	825
BUS-0017	33000	1064	841	825
BUS-0027	11000	0	4176	2920
BUS-0029	433	39087	43701	36734
BUS-0049	433	33753	37697	33513
BUS-0053	11000	0	4203	2927
BUS-0066	33000	1066	842	826
COOLING TOWER	433	5284	10076	9714
FUEL & ASH HAN	433	26397	30445	28967
INCOMER TO SA	33000	857	776	746
MAIN LV BUS	433	36598	43095	36676
METERING ROOM	33000	857	766	746
RING MAIN UNIT	33000	1064	841	825
TG AUX SPARE	433	26434	30540	29031
VCB PANEL	11000	0	4194	2925

V. RESULT AND DISCUSSION

The load flow analysis provides a solution to study systems under real or hypothetical conditions. The solution results should be evaluated and analysed with respect to optimum present and future operations. This leads to a diagnosis of

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the existing system. The analysis also helps to improve operations and provide a meaningful basis for future system planning. Load flow analysis form the basis for determining both when new equipment additions are needed and the effectiveness of new alternatives to solve present deficiencies and meet future system requirements.

From the load flow analysis, it has been observed that voltage drops taking place at various buses at Cooling tower bus is 11.04%, Main LV bus 6.42%, ACDB bus is 6.42%. The voltage drop in cable from main LV bus to cooling tower is 4.62%. The overall system loss is found to be 323KW. From actual observations values found from simulations are very close and satisfactory. Capacitor bank can be used to compensate this voltage drops taking place due to several motors used in biomass power plant which are inductive in nature.

This single line model can be used the basis for various studies such as Transient motor starting (TMS), Industrial Simulation (ISIM), Harmonic analysis (HIWAVE), Stability analysis, DC system analysis, harmonic studies, Equipment evaluation, Fail input evaluation, Fail equipment evaluation and Arc Flash evaluation etc

VI. FUTURE SCOPE

This work has focused on the modelling and simulation of 6 MW biomass power plant through balance system studies option in SKM software, generates the report on the load flow & fault analysis to observe the relationship between the real and reactive power loadings of each elements of the network. This work can be extended by generating additional reports with the same simulation such as Time current characteristics plotting for further protective relay co-ordination and other studies.

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