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"Load Flow Analysis of 11/3.3kV (Substation) Electricity Sub Center Padmapur (W.C.L.), District Chandrapur"

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Abstract: In power system the power flow analysis (also known as load flow study) is an important tool used for analysis of power system. Load flow studies helps in determining the bus voltages, phase angles, active, reactive power, losses, power factor, etc. at different buses, generators, transformer in balanced and unbalanced conditions. For the analysis of load flow, methods generally used are Gauss-Seidel method, Newton-Raphson method and Fast Decoupled method. Newton-Raphson method is comparatively better for radial system hence; this method is identified for load flow analysis. Our scheme for load flow analysis is 11/3.3 kV Electricity Sub centre Padmapur W.C.L. Substation, Chandrapur for which all the parameters are calculated and compare with simulation results. ETAP (Electrical Transient and Analysis Program) software used for the simulation of scheme and the results from substation are compared with the simulation results.

Keywords: Load flow analysis, Electrical transient analyser program, Simulation, Capacitor banks, Voltage profile, Loss reduction.

I. INTRODUCTION

In our country the energy demands are increasing day by day and there is a need to fulfill these demands as power is essential for sustainable development of a country, for this purpose expansion of power system is necessary. As the size of power system increases the probability of faults also increases. For large power system manual power flow analysis is not recommended as it is not time efficient and prone to manual errors thus Electrical transient analyser program (ETAP) is used, ETAP Load Flow software performs power flow analysis and voltage drop calculations with accurate and reliable results. ETAP load flow calculation program calculates bus voltages, branch power factors, currents, and power flows throughout the electrical system.

Voltage drop is most common problem in heavily loaded power system. In power system there is some allowable variation in voltage levels but in heavily loaded power system these voltage levels are not maintained in the desired tolerance limit. With drop in voltage at constant power demand the current drawn by the system increases and thus copper losses in the system increases and overall system efficiency reduces, these system losses can not be left unattended thus to reduce the voltage drop and to maintain voltage profile of the system various methods of voltage control can be adopted, most common methods are method of voltage control is tap setting of transformer but it has some limitation related to insulation and dielectric strength, capacitor banks can be installed near to the load having large voltage drops.

II. LOAD FLOW ANALYSIS

Load flow analysis gives the information regarding power generation, power delivered and losses occur in the system, current through each branch, active and reactive power, voltages at each bus, etc. Here we are using Load Flow analysis to study & to check the performance of existing system. Load-flow studies are probably the most common of all power system analysis calculations. The load flow simulations here carried out for identifying best operating conditions provided under the guidelines of process requirements. Load-flow analysis is executed to find the sensitivity of feeder status with variation of power loading, conductor length, and total capacity of distribution transformers. For the analysis of load flow, methods generally used are Gauss-Seidel method, Newton-Raphson method and Fast Decoupled method. This project makes effective use of Electrical Transient Analyzer Program (ETAP) to carry out load flow analysis of 11/3.3 kV substation.

III. SYSTEM UNDER CONSIDERATION

Single line diagram of 11/3.3kV (substation) Electricity sub centre Padmapur (W.C.L.), district Chandrapur is shown in fig below

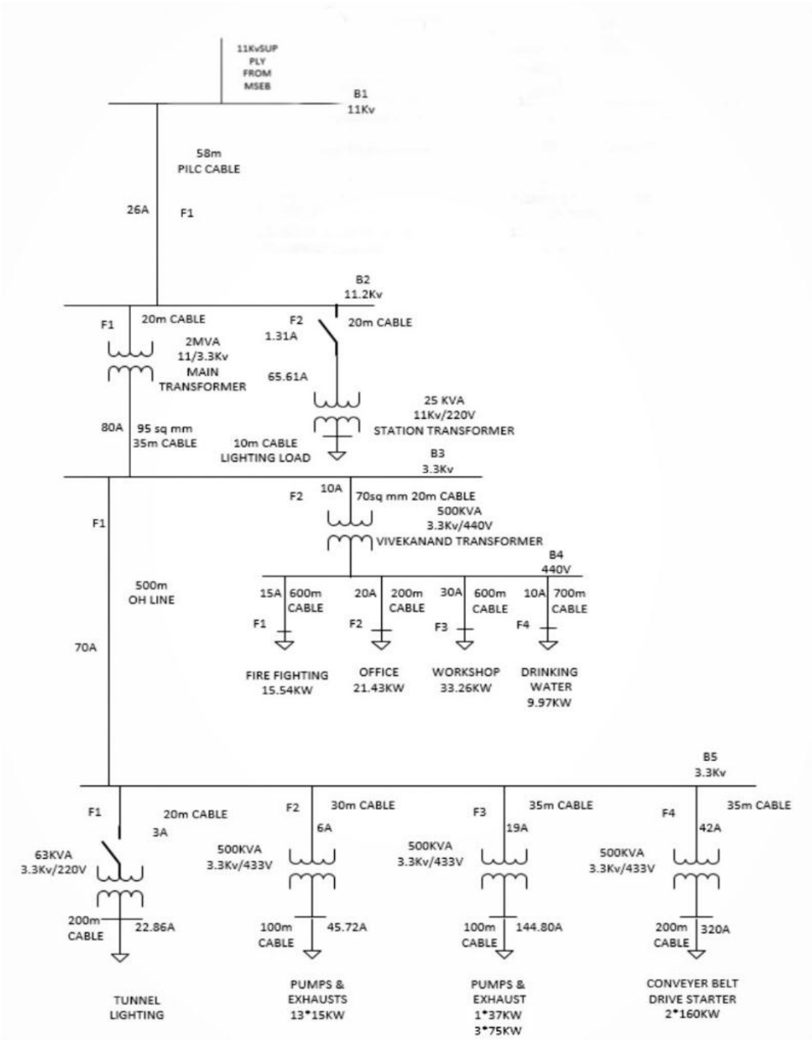

Fig. 1: Single line diagram of substation

11/3.3kV Padmapur substation receives 11kV supply from MAHAGENCO, the 11kV supply is fed to busbar B1. From busbar B1 feeder F1 is connected to busbar B2. From busbar B2, feeder F1 is connected to 2MVA transformer and feeder F2 is connected to 25kV station transformer. The station transformer is use to power the station equipment. The 2MVA transformer feds the busbar B3, from busbar B3 feeder F1 goes to the CHP (Coal Handling plant) at busbar B5, CHP supplies power to tunnel lighting, exhaust fans, conveyer belts through feeder F1, F2, F3, F4. feeder F2 of busbar B3 is connected to 500KVA transformer, this transformer feds other sectors like offices, workshops, drinking water and firefighting department from busbar 4. The feeder F1 from busbar 3 transfers the power to CHP.

Table: 1 Rating of substation transformer.

No. of transformers	KVA rating	Volts (no load)		Ampere		Type of connection	Type of transformer
		H.V.	L.V.	H.V.	L.V.		
1	2000	11000V	3400V	10.5A	339.62A	Delta-star	ONAN
1	25	11000V	220V	1.31A	65.61A	Delta-star	ONAN
4	500	3300V	433V	87.5A	668A	Delta-star	ONAN
1	63	3300V	220V	11A	165A	Delta-star	ONAN

Table: 2 Type, Size and Length Of Feeder At Bus 1

Bus 1 (11 kV)			
Parameters	Feeder 1	Feeder 2	Feeder 3
Method of laying	Underground cable	Underground cable	Underground cable
Type	PILC	PILC	PILC
Size	$70mm^2$	-	-
length	58m	60m	60m

Table: 3 Type, Size and Length of Feeder at Bus-2,3

	BUS 2 (11kV)		BUS 3 (3.3 kV)	
Parameters	Feeder 1	Feeder 2	Feeder 1	Feeder 2
Method of laying	Underground cable	Underground cable	Overhead line	Underground cable
Type	PILC	PILC	AAAC	PILC
Size	LV side: $35mm^2$ HV side: $95mm^2$	LV side: $35mm^2$ HV side: $70mm^2$	$111mm^2$	HV side: $70mm^2$
length	LV side: 20m HV side: 35m	LV side: 20m HV side: 10m	500m	20m

Table: 4 Type, Size and Length of Feeder at Bus-4

BUS 4 (440V)				
Parameters	Feeder 1	Feeder 2	Feeder 3	Feeder 4
Method of laying	Underground cable	Underground cable	Underground cable	Underground cable
Type	PILC	PILC	PILC	PILC
Size	$4mm^2$	$4mm^2$	$4mm^2$	$4mm^2$
Length	600m	200m	600m	700m

Table: 5 Type, Size and Length of Feeder at Bus-5

BUS 5 (3.3 kV)				
Parameters	Feeder 1	Feeder 2	Feeder 3	Feeder 4
Method of laying	Underground cable	Underground cable	Underground cable	Underground cable
Type	PILC	PILC	PILC	PILC
Size	$25mm^2$	$50mm^2$	$50mm^2$	$50mm^2$
Length	20m	30m	35m	35m

IV. SIMULATION OF SYSTEM ON ETAP

The single line diagram of 11/3.3 kV substation shown in fig.1 has been considered for load flow analysis. The simulation has been carried out in ETAP software to determine the power transfer, losses occurring in the system, power factor and to determine the voltage profile of the system. The capacitor banks are connected near to the load side in CHP. The simulation results of the system with and without capacitor are then compared.

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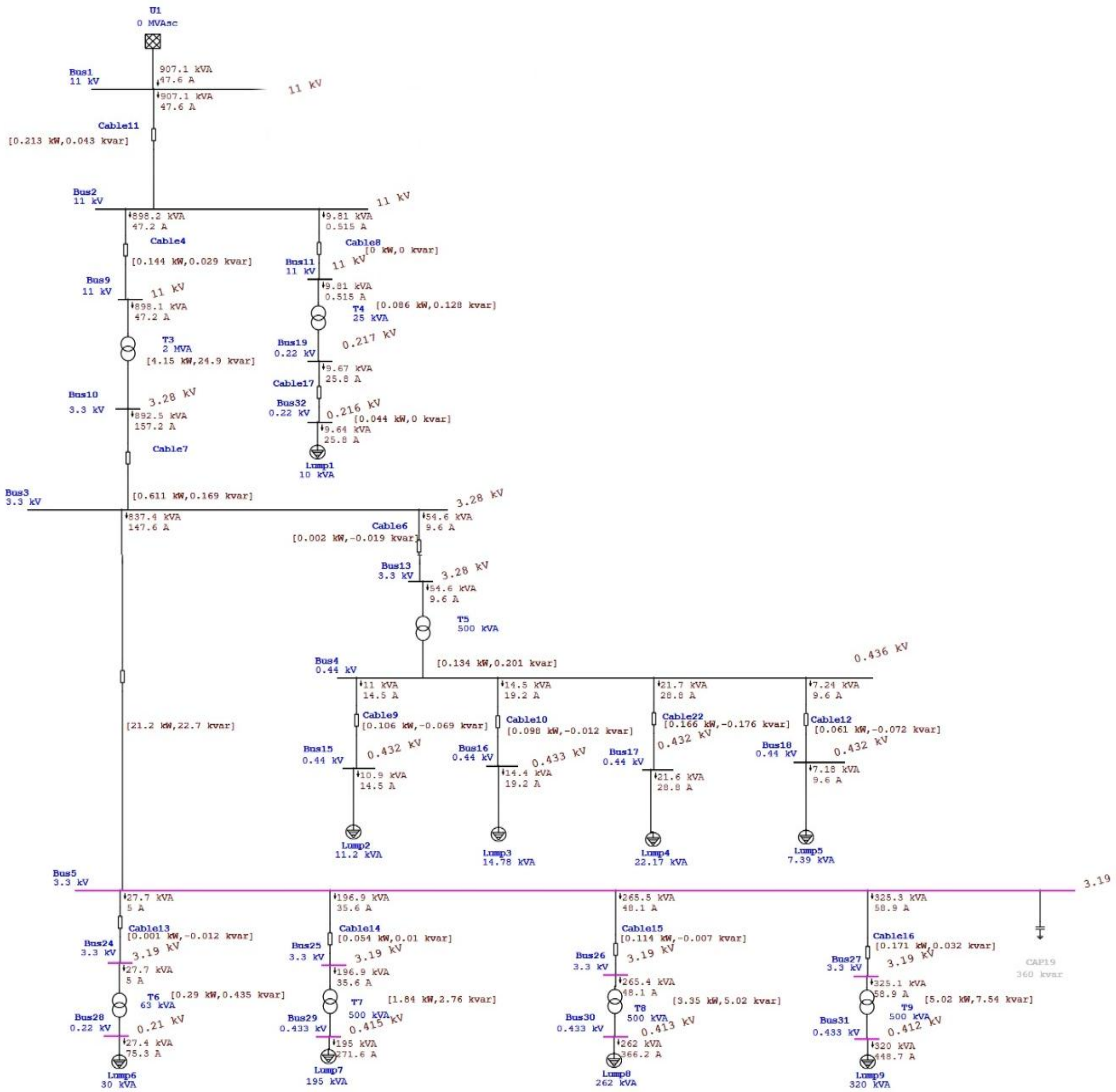

Fig.2 Simulated scheme of substation without capacitor bank in ETAP

There was large amount of voltage drop near to the load end at CHP and hence to compensate the voltage drop capacitor bank is installed on bus 5 in CHP. After installing capacitor there was significant improvement in voltage profile of system, losses occurred in the system were reduced and power factor of the system improved, tables below shows comparison between system performance of the power system with and without capacitor bank.

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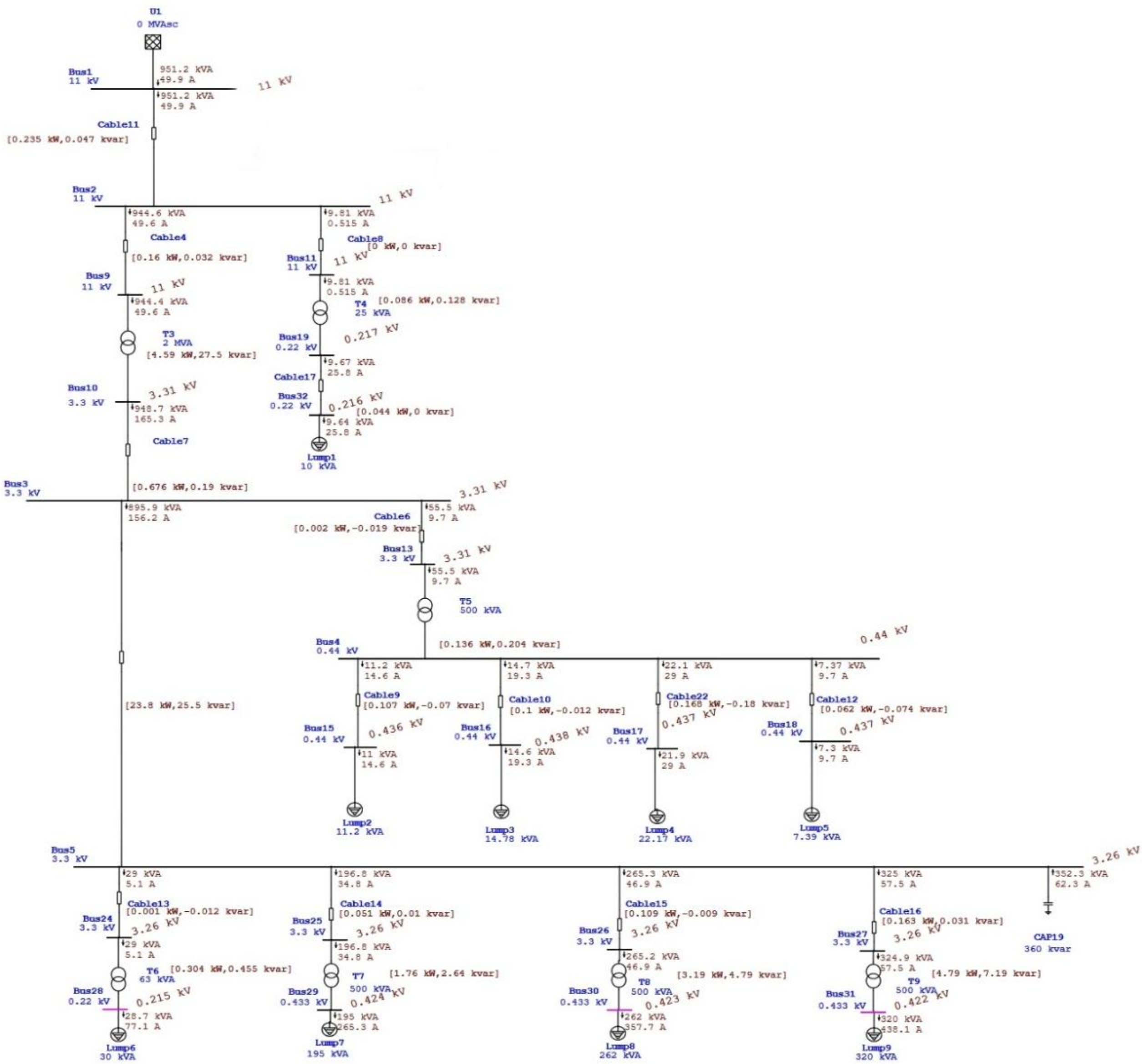

Fig.3 Simulated scheme of substation with capacitor bank in ETAP

Simulation Result With And Without Capacitor In Tabular Form

Table: 6 Simulation Result for Bus Voltages

Bus ID	Voltage without capacitor in kV	Voltage with capacitor in kV
Bus 1	11	11
Bus 2	11	11
Bus 9	11	11
Bus 10	3.28	3.31
Bus 11	11	11
Bus 19	0.217	0.217
Bus 32	0.216	0.216
Bus 3	3.28	3.31
Bus 13	3.28	3.31
Bus 4	0.436	0.440
Bus 15	0.432	0.436
Bus 16	0.433	0.438
Bus 17	0.432	0.437
Bus 18	0.432	0.437

Bus 5	3.19	3.26
Bus 24	3.19	3.26
Bus 28	0.210	0.215
Bus 25	3.19	3.26
Bus 29	0.415	0.424
Bus 26	3.19	3.26
Bus 30	0.413	0.423
Bus 27	3.19	3.26
Bus 31	0.412	0.422

Chart: 1 Simulation Results For Bus Voltage

Data regarding this chart is taken from Table: - 6

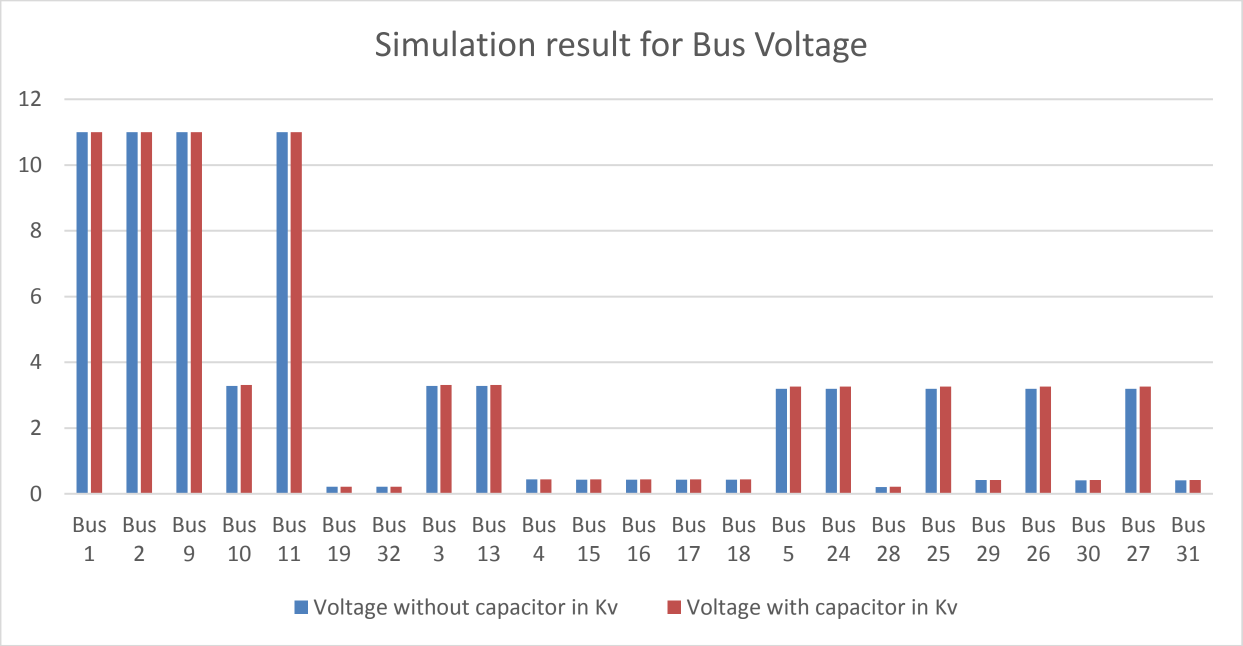

Table: -7 Simulation Result for Current

Bus ID	**Current without capacitor in Ampere**	**Current with capacitor in Ampere**
Bus 24	5	5.1
Bus 28	75.3	77.8
Bus 25	35.6	34.8
Bus 29	271.6	265.3
Bus 26	48.1	46.9
Bus 30	366.2	357.7
Bus 27	58.9	57.5
Bus 31	448.7	438.1

Chart: 2 Simulation Results for Current

data regarding this chart is taken from table: - 7

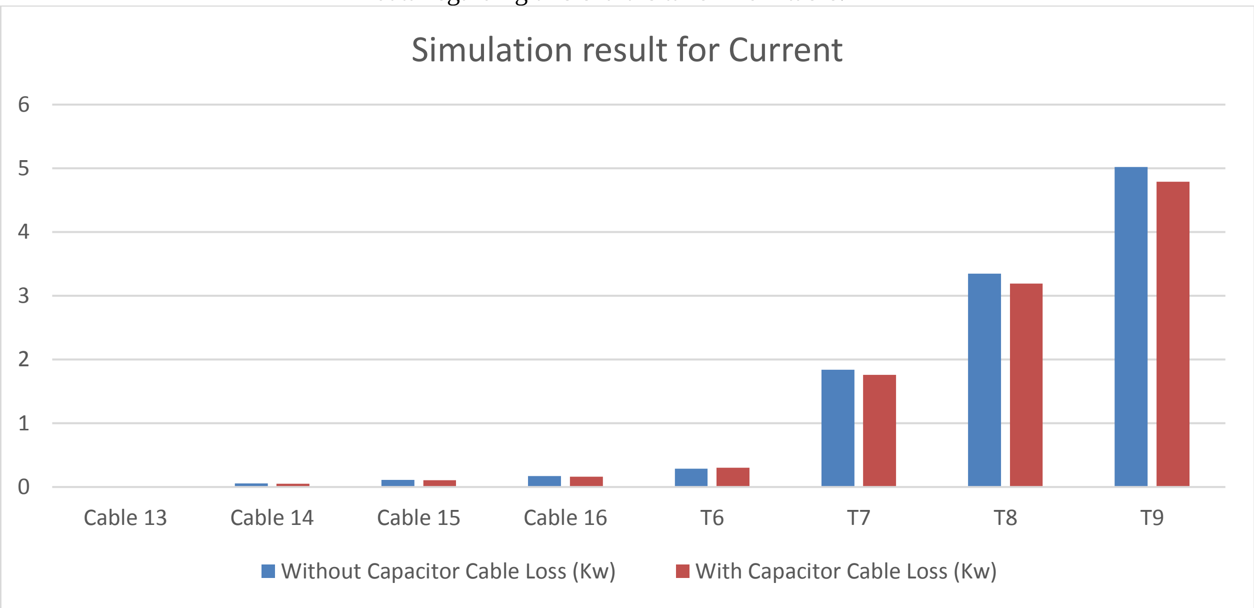

Table: -8 Simulation Result For Cable And Transformer Losses In CHP

Component	**Without Capacitor Loss (kW)**	**With Capacitor Loss (kW)**
Cable 13	0.001	0.001
Cable 14	0.054	0.051
Cable 15	0.114	0.109
Cable 16	0.171	0.163
T6	0.29	0.304
T7	1.84	1.76
T8	3.35	3.19
T9	5.02	4.79

Chart: 3 Simulation Result For Cable And Transformer Losses In CHP

Data regarding this chart is taken from table: - 8

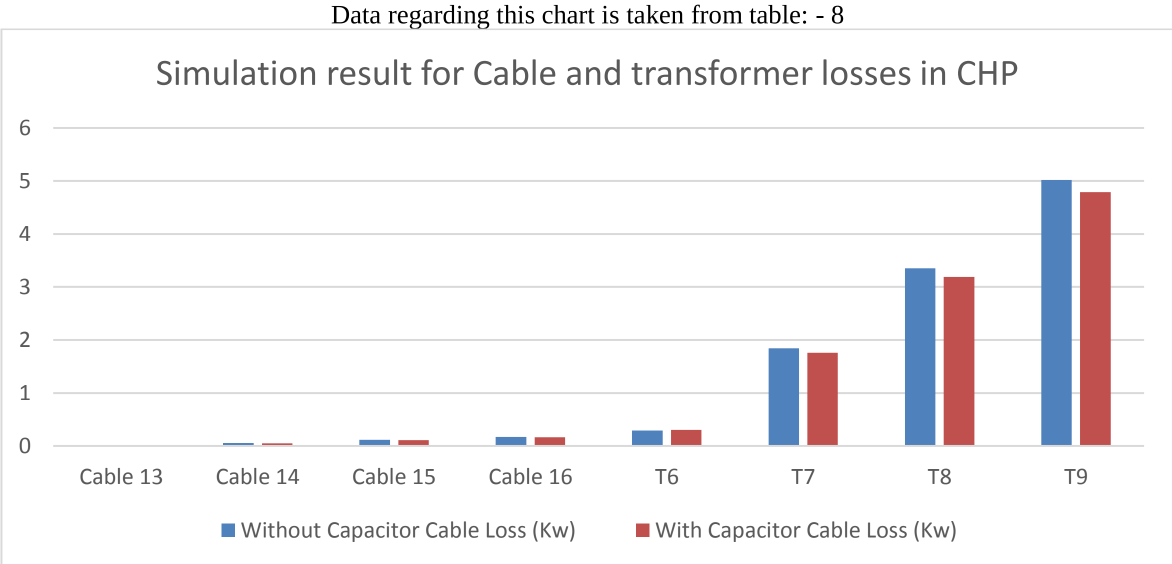

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Table: - 9 Total Losses at Chp

Parameter	Without Capacitor	With Capacitor
Power Factor (%)	99.71 lag	99.03 leading
Power losses (KW)	10.84	10.36
Apparent Losses (KVar)	15.778	15.095
Power Saving	0.12KW = 1.10%	

Chart: 4 Losses Of CHP

data regarding this chart is taken from table: - 9

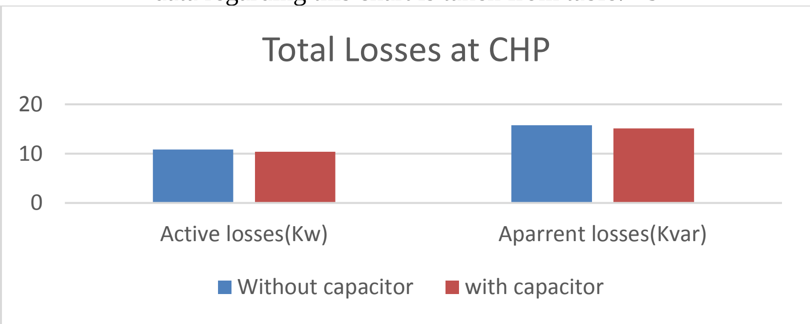

Table: -10 Marginal Report Without Capacitor

Device ID	Type	Condition	Rating	Unit	Operating	%Operating
Bus 24	Bus	Undervoltage	3.300	kV	3.19	96.7
Bus 25	Bus	Undervoltage	3.300	kV	3.19	96.6
Bus 26	Bus	Undervoltage	3.300	kV	3.19	96.6
Bus 27	Bus	Undervoltage	3.300	kV	3.19	96.6
Bus 28	Bus	Undervoltage	0.220	kV	0.21	95.6
Bus 29	Bus	Undervoltage	0.433	kV	0.41	95.7
Bus 30	Bus	Undervoltage	0.433	kV	0.41	95.4
Bus 31	Bus	Undervoltage	0.433	kV	0.41	95.1
Bus 5	Bus	Undervoltage	3.300	kV	3.19	96.7

Table: - 11 Marginal Report With Capacitor

Device ID	Type	Condition	Rating	Unit	Operating	%Operating
Bus 28	Bus	Undervoltage	0.220	kV	0.215	97.9
Bus 30	Bus	Undervoltage	0.433	kV	0.420	97.7
Bus 31	Bus	Undervoltage	0.433	kV	0.420	97.4

SIMULATION RESULT WITHOUT CAPACITOR

The system shown in fig simulated using ETAP software for system parameters shown.
Fig. 2 shows the results for power flow analysis using Newton Raphson method. Fig.2 shows the value of voltages at each and every bus. It can be observed that, there is undervoltage at bus-5,24,25,26,27,28,29,30 and 31 and are shown in pink colour indicating that the values are within marginal limit.
Table.7 indicates that current flowing through various buses in CHP are comparatively higher than the value of current in with capacitor simulation

SIMULATION RESULT WITH CAPACITOR

The system shown in fig simulated using ETAP software for system parameters shown.
Fig.3 shows the results for power flow analysis using Newton Raphson method. Fig.3 shows the value of voltages at each and every bus. It can be observed that there is undervoltage at bus-28,30 and 31 and are shown in pink colour indicating that the values are within marginal limit.
Table.7 indicates that current flowing through various buses in CHP are comparatively lower than the value of current in without capacitor simulation. Lower current means reduced I^2R losses and improved system performance.

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V. CONCLUSION

After simulating the substation scheme on ETAP software with all the parameters obtained from the substation it is observed that there is marginal voltage situation near at several buses in CHP, to overcome this situation it is recommended to install capacitor bank near to the load to compensate the drop in voltage. After connecting capacitor bank active power loss reduced to 1.10% and power factor improved from 0.99lagging to 0.99leading.

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