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Design and Analysis of Typical Chemical Industry Electrical Distribution System for Voltage Profile Improvement

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Abstract – *Chemical industry terminals are coming up at various places in the country. The plants are very sensitive to environment and fire. It needs 24x7 power supply. Precise power system studies have to be carried out as any interruption of supply would result into loss to industrial consumers. The paper here brings out details of the study and appropriate solution for electrification of the typical industrial plant. Paper presents design of installation and operation logic. Various cases covering sequence of operation under each option will also be given. They will be supported with single line diagram and system study results. Design and Load flow analysis of the typical chemical industry electrical distribution system are done using ETAP software.*

Key Words: Load Flow Analysis, Industrial Electrification, Chemical Industry, ETAP, Distribution System

1. INTRODUCTION

Distribution system is that element of Power system which distributes power to the consumers for utilization. It is ultimate and revenue related part in Power System. Various kinds of loads are connected to distribution system. Now-a-days the electricity demand keeps on increasing. The distribution network designed for certain amount of loads may not able to fulfill the increased demand after many years. Thus, there arises the need to analyze the existing network and replace it with healthy network if needed. In this paper, actual existing large scale chemical industry is considered. Existing distribution network of industry with extended load is designed and analyzed using ETAP software. Load flow study is an important tool for the design and operation of distribution systems. At the design stage, it is applied to ensure that voltage and current are satisfactory under various conditions all over the network. At the operation stage, it is used to ensure that voltage and currents are within predefined ranges for expected loads.

Paper [1] describes about the fundamental aspects of industrial power distribution. Paper [2] describes about the design, analysis and loss optimization of 11 kV urban distribution system using ETAP Software. From this analysis, voltage regulation is improved, losses are minimized and revenue is increased of the system. Paper [3] describes about a new optimal bus design methodology considering reliability and economics of distribution substation. Paper [4] describes about reconfiguration of 11 kV distribution network feeding residential rural loads in Middle Egypt. Reconfiguration improves the behavior of the network, releases more capacity of the same existing assets and reduces the power losses. Paper [5] describes about the planned and effective IEEE 15 and IEEE 13 radial distribution network designed with the help of Load flow analysis to cope up with an ever growing demand. Paper [6] describes about the performance 11KV underground secondary distribution network with diurnal variation of load demand and 500 KWp distributed Solar Photovoltaic penetration at IIT Gandhinagar. Capacitor bank installation can meet the reactive power demand locally and improve the node power factor which further reduces the network losses. Paper [7] describes about the study of 11 kV distribution network of Jaipur city. The test system is analyzed with and without capacitor bank. There is reduction of losses, reduction in loading and improvement in voltage profile by placing capacitor bank in distribution network. Paper [8] describes about the study of 113 bus radial distribution system with overloaded, long-length lines and high level of power dissipation by using ETAP software. From the load flow analysis, voltage profile improvement and power loss reduction is achieved in the proposed network. Paper [9] describes about the 132 kV GEPCO region grid simulation in ETAP software. Off-line monitoring and analysis is made in ETAP based upon recorded data obtained from an actual 132 kV grid which can be useful for utilities in their planning and development sections and for converting conventional grid network into smart grid. Paper [10] describes about the Grid Analysis drawing Almajd factory, a real plant installed in Libya to evaluate the grid stability state. Optimal load flow analysis, Harmonic analysis and Motor starting Analysis is carried out on whole model in ETAP software to analyse the grid state in off-line mode. Literature [11], [12] gives the detailed idea of substation design and [13] gives the detailed idea of practical implementation of distribution network design in Electrical Transient and Analysis Program Software.

The paper here brings out details of the study and optimized solution for electrification of the typical chemical industrial plant. The objectives of this paper are: (1) To design and analyze existing chemical industrial plant using ETAP software (2) To design new load flow optimized distribution network of chemical industry if needed (3) To carry out load flow analysis of proposed distribution network.

2. 11KV DISTRIBUTION NETWORK DESIGN

2.1 Existing Network Design

The result of Load Flow Analysis of existing distribution network is as under:

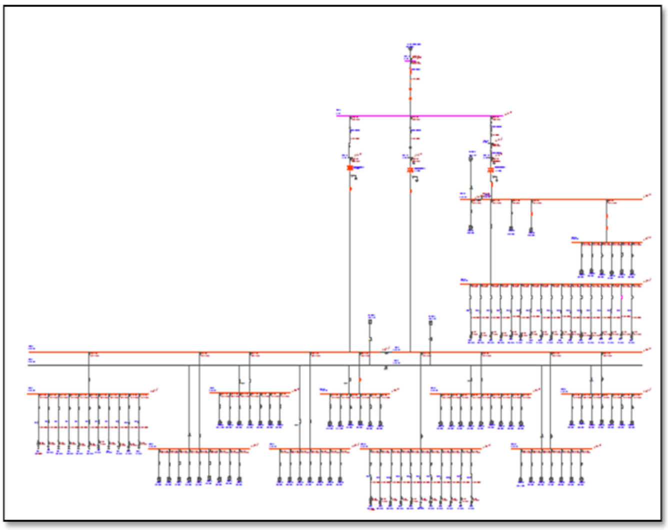

Fig -1: Existing distribution network in ETAP software

Table -1: Existing System report

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
BUS- 11	Bus	Under Voltage	0.415	kV	0.384	92.5	3-Phase
BUS- 12	Bus	Under Voltage	0.415	kV	0.38	92.5	3-Phase
BUS- 12	Bus	Overload	5000.000	Amp	7546.38	150.9	3-Phase
BUS- 13	Bus	Under Voltage	0.415	kV	0.39	93.8	3-Phase
BUS- 14	Bus	Under Voltage	0.415	kV	0.39	93.8	3-Phase
BUS- 15	Bus	Under Voltage	0.415	kV	0.39	93.8	3-Phase
BUS- 16	Bus	Under Voltage	0.415	kV	0.39	93.8	3-Phase
BUS- 17	Bus	Under Voltage	0.415	kV	0.39	93.8	3-Phase
BUS- 18	Bus	Under Voltage	0.415	kV	0.39	94.9	3-Phase
BUS- 19	Bus	Under Voltage	0.415	kV	0.39	94.9	3-Phase
BUS- 20	Bus	Under Voltage	0.415	kV	0.39	94.9	3-Phase
BUS- 21	Bus	Under Voltage	0.415	kV	0.39	94.9	3-Phase
BUS- 22	Bus	Under Voltage	0.415	kV	0.38	92.5	3-Phase
BUS- 23	Bus	Under Voltage	0.415	kV	0.38	92.5	3-Phase
BUS- 7	Bus	Under Voltage	0.415	kV	0.39	93.8	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
BUS- 7	Bus	Overload	5000.000	Amp	6814.610	136.3	3-Phase
BUS- 8	Bus	Under Voltage	0.415	kV	0.39	94.9	3-Phase
BUS- 8	Bus	Overload	5000.000	Amp	5944.98	118.9	3-Phase
FUSE	Fuse	Overload	200.000	Amp	797.13	398.6	3-Phase
HBCB-2	HV CB	Overload	630.000	Amp	797.13	126.5	3-Phase
HVCB-1	HV CB	Overload	630.000	Amp	797.13	126.5	3-Phase
LVCB-1	LV CB	Overload	5000.000	Amp	6814.63	136.3	3-Phase
LVCB-122	LV CB	Overload	2000.000	Amp	2059.23	103.0	3-Phase
LVCB-18	LV CB	Overload	800.000	Amp	843.39	105.4	3-Phase
LVCB-27	LV CB	Overload	800.000	Amp	803.25	100.4	3-Phase
LVCB-28	LV CB	Overload	800.000	Amp	803.25	100.4	3-Phase
LVCB-5	LV CB	Overload	5000.000	Amp	5945.01	118.9	3-Phase
LVCB-9	LV CB	Overload	5000.000	Amp	7546.40	150.9	3-Phase
TRANSFORMER-1	Transformer	Overload	2.500	MVA	5.01	200.5	3-Phase
TRANSFORMER-2	Transformer	Overload	2.500	MVA	4.38	175.0	3-Phase
TRANSFORMER-3	Transformer	Overload	2.500	MVA	5.55	221.9	3-Phase
XLPE CABLE	Cable	Overload	444.393	Amp	797.13	179.4	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
BUS- 1	Bus	Overload	800.000	Amp	796.437	99.6	3-Phase
BUS- 2	Bus	Overload	800.000	Amp	797.13	99.6	3-Phase
LVCB-119	LV CB	Overload	63.000	Amp	61.81	98.1	3-Phase

The result shows that there is the need to reconfigure the network according to the present load demand.

2.2 Proposed Network Design

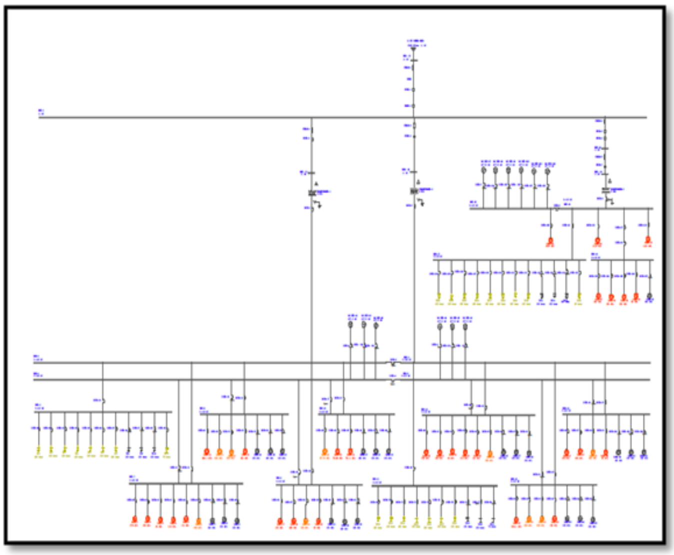

Fig -2: Single Line Diagram of proposed distribution network

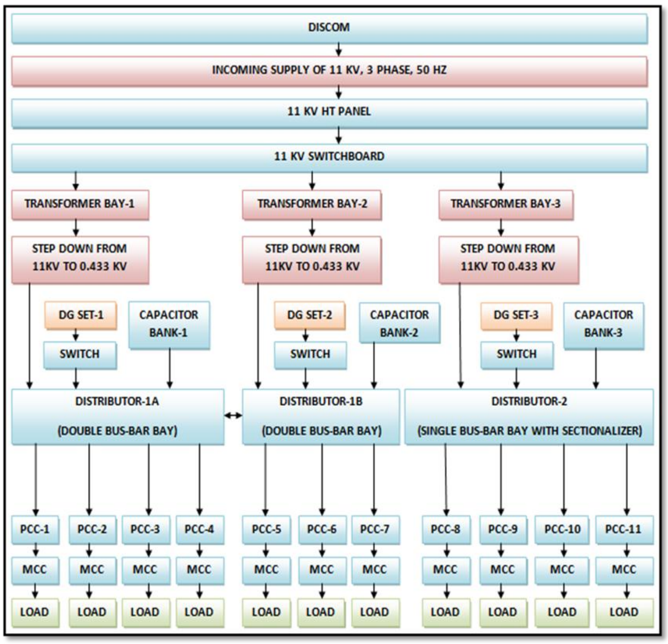

Fig -3: Block Diagram of proposed distribution network

In this design, 3 phase, 11 kV, 50 Hz supply comes from Distribution Company. It passes through two pole structure with lightning arrestor and drop out fuse and reaches 11 kV indoor High Tension Panel. From here, the power flows through 11 kV switchboard. From 11 kV switchboard, power flows through transformer bay-1, transformer bay-2 and again 11 kV switchboard for provision of future expansion of load and then to transformer bay-3, all three simultaneously. Here, three delta-star distribution transformers are used due to advantages like harmonic suppression and grounding isolation which step down the voltage from 11 kV to 0.433 kV.

Transformer bay-1 enters into main Low Tension Panel and capacitor Panel and connects to main bus. Here, duplicate bus-bar system consisting of main bus-bar and spare bus-bar is used. The incoming and outgoing lines can be connected to either bus with the help of bus coupler which consists of a circuit breakers and isolators. Normally, the incoming and outgoing lines remain connected to the main bus. In case of repair of main bus or fault occurring on it, the continuity of the supply to the critical loads can be maintained by transferring it to spare bus. On spare bus-bar 415 V DG set is provided as a backup during outage. In the same way, transformer bay-2 is connected. Both distributor-1A and distributor-1B are connected with each other through bus coupler so that if any transformer fails to operate, the power can be supplied through another transformer. Thus, reliability of the system is increased. Transformer bay-3 enters into Main Low Tension Panel and Capacitor Panel and connects with single bus-bar system with sectionalisation. The single bus is divided into two sections. Circuit breaker is used as the sectionalizing switch so that uncoupling of the two buses may be carried out safely during load transfer and it is provided by isolators on both sides so that its maintenance can be carried out while the two buses are alive. Each section of bus behaves as a separate bus-bar. DG set is provided on one bus bar bay as a backup during outage. The main advantages for this type of arrangement are- Firstly, if a fault occurs on any section of the bus, that section can be isolated without affecting the other sections supply; Secondly, if a fault occurs on any line, the fault current is much lower than with the unsectionalized bus-bar which permits the use of circuit breakers of lower capacity in the lines; Thirdly, repairs and maintenance of any section of the bus can be carried out by de-energising that particular section only, mitigating the possibility of complete shutdown.

On distributor-1A, 4 lines of service mains are provided, on distributor-1B, 3 no. of service mains are provided and on distributor-2, 4 lines of service mains are provided which are connected to electrical loads. Now, in industry various types of loads are there. To feed the power to them, we need some system like control center so that we can control and monitor the power flow. So here, control panels/control centers come into picture. PCC (Power Control Center) are primary type of control center which controls power which is going to utilize in industry. From PCC, power is fed to MCC (Motor Control Center) situated at different locations near the loads (mostly motors), and from MCC loads are connected. Many spare feeders are also considered at each PCC for the future expansion of load. In the given Single Line Diagram, various types of measurement and protection devices are used like Relays, Vacuum Circuit Breaker, Air Circuit Breaker, Molded Case Circuit Breaker, etc. Also, different types of interlocking schemes are provided on Circuit Breakers as per requirement. Load Flow analysis is done for the design of this typical large scale chemical industrial plant using Adaptive Newton Raphson Method.

2.3 Load Estimation

The calculation and analysis of load for industrial plant is done. The theoretical result obtained is as under:

Load Type = 80% Constant KVA and 20% constant Z

Load Voltage = 415 V

Load Current = 16640 A

Load Power Factor = 85%

Total Connected Load = 9.76 MVA = 8.3 MW

Total Spare Load = 2.2 MVA = 1.87 MW

On the basis of Load data, the current calculation of other electrical equipments is done by applying Kirchhoff's Current Law.

3. RESULTS

The distribution network is designed as per IEC i.e., International Electrotechnical Standard at 50 Hz. The ETAP file is simulated for different conditions and the results obtained are obtained. Notifications for different cases related to Load Flow Analysis are:

NC	NORMAL CONDITION
LI	FUTURE LOAD INCREMENT
T1F	ONLY TRANSFORMER 1 BAY FAILURE
T2F	ONLY TRANSFORMER 2 BAY FAILURE
T3F	ONLY TRANSFORMER 3 BAY FAILURE
T12F	BOTH TRANSFORMER -1 AND -2 BAY FAILURE
T123F	ALLTRANSFORMER -1, -2 AND -3 BAY FAILURE

Below table contain different equipments (Transformers, DG sets and Capacitor banks) ratings which are in service condition along with total load ratings in each case:

Table -2: Design Operation

CONDITION	NC	LI	T1F	T2F	T3F	T12F	T123F
XMER-1 (MVA)	5	5	-	5	5	-	-
XMER-2 (MVA)	5	5	5	-	5	-	-
XMER-3 (MVA)	5	5	5	5	-	5	-
DG SET-1 (MVA)	-	-	-	-	-	2.25	2.25
DG SET-2 (MVA)	-	-	-	-	-	2.25	2.25
DG SET-3 (MVA)	-	-	-	-	4.5	-	4.5
CAP. BANK - 1 (MVAR)	0.775	1.075	0.575	0.575	0.575	-	-
CAP. BANK - 2 (MVAR)	0.7	0.975	0.7	0.7	0.4	-	-
CAP. BABK -3 (MVAR)	0.85	1.15	0.85	0.85	-	0.85	-
TOTAL LOAD (MVA)	9.5643	11.964	7.7765	7.7765	9.5643	7.7765	7.7765

Results of Load Flow Analysis of Design are as under:

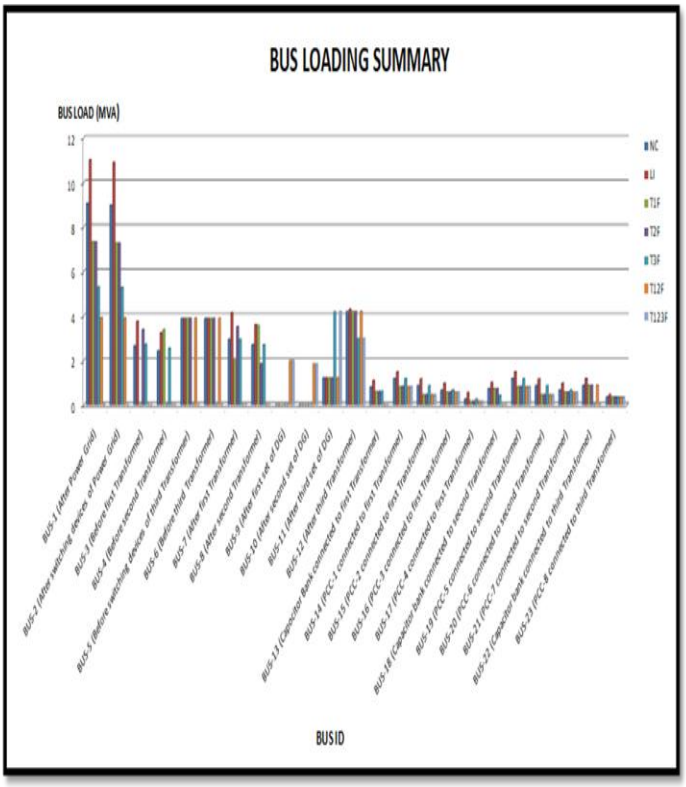

Fig -4: Bus Loading Summary

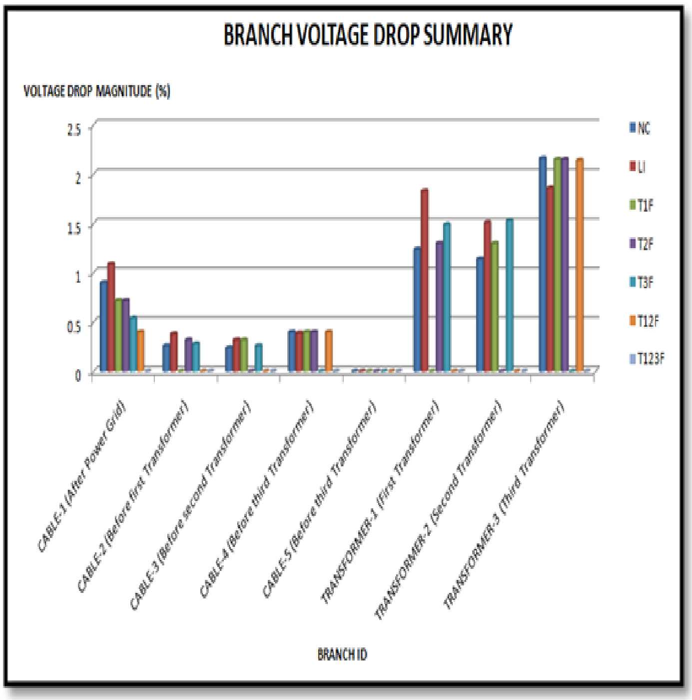

Fig -5: Branch Voltage Drop Summary

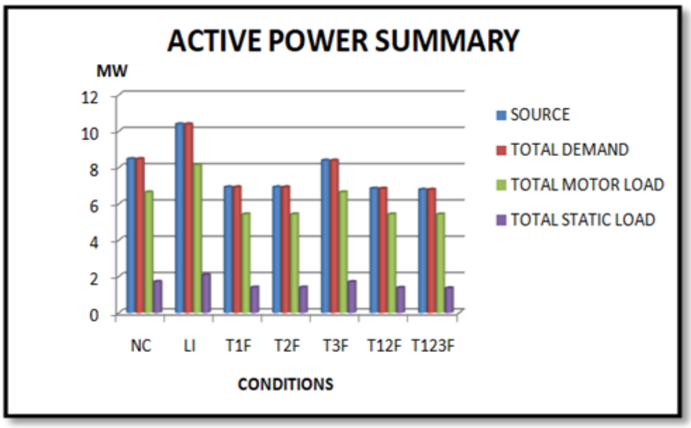

Fig -6: Active Power Summary

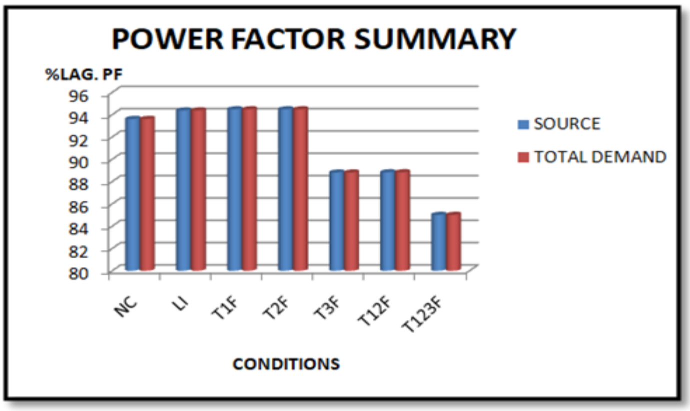

Fig -7: Power Factor Summary

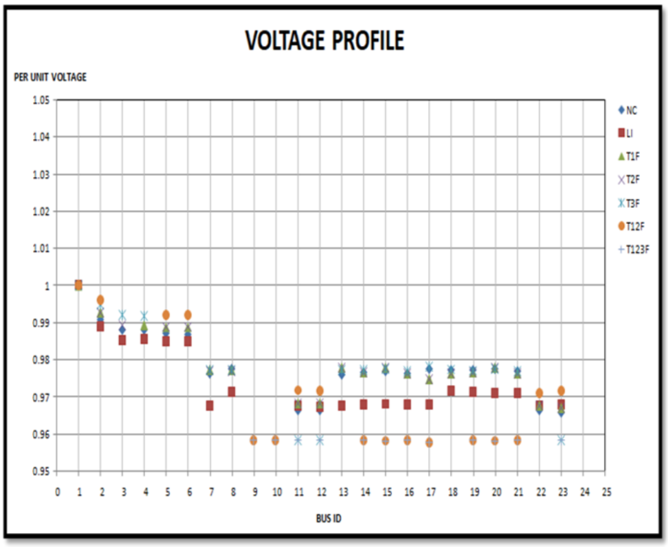

Fig -8: Voltage Profile Summary

Table -3: Voltage Profile Comparison during Normal Condition

BUS NO.	OPERATING P.U. VOLTAGE OF EXISTING SYSTEM	OPERATING P.U. VOLTAGE OF PROPOSED SYSTEM
1 (V_B=11.00 kV)	1.000 (V_A=11.00 kV)	1.000 (V_A=11.00 kV)
2 (V_B=11.00 kV)	0.985 (V_A=10.84 kV)	0.991 (V_A=10.90 kV)
3 (V_B=11.00 kV)	0.980 (V_A=10.79 kV)	0.988 (V_A=10.87 kV)
4 (V_B=11.00 kV)	0.980 (V_A=10.79 kV)	0.988 (V_A=10.87 kV)
5 (V_B=11.00 kV)	0.983 (V_A=10.81 kV)	0.987 (V_A=10.86 kV)
6 (V_B=11.00 kV)	0.980 (V_A=10.78 kV)	0.987 (V_A=10.86 kV)
7 (V_B=0.433 kV)	0.898 (V_A=0.389 kV)	0.977 (V_A=0.423 kV)
8 (V_B=0.433 kV)	0.910 (V_A=0.394 kV)	0.977 (V_A=0.423 kV)
11 (V_B=0.433 kV)	0.887 (V_A=0.384 kV)	0.965 (V_A=0.418 kV)
12 (V_B=0.433 kV)	0.887 (V_A=0.384 kV)	0.965 (V_A=0.418 kV)
13 (V_B=0.433 kV)	0.898 (V_A=0.389 kV)	0.977 (V_A=0.423 kV)
14 (V_B=0.433 kV)	0.898 (V_A=0.389 kV)	0.977 (V_A=0.423 kV)
15 (V_B=0.433 kV)	0.898 (V_A=0.389 kV)	0.977 (V_A=0.423 kV)
16 (V_B=0.433 kV)	0.898 (V_A=0.389 kV)	0.977 (V_A=0.423 kV)
17 (V_B=0.433 kV)	0.898 (V_A=0.389 kV)	0.977 (V_A=0.423 kV)
18 (V_B=0.433 kV)	0.910 (V_A=0.394 kV)	0.977 (V_A=0.423 kV)
19 (V_B=0.433 kV)	0.910 (V_A=0.394 kV)	0.977 (V_A=0.423 kV)
20 (V_B=0.433 kV)	0.910 (V_A=0.394 kV)	0.977 (V_A=0.423 kV)
21 (V_B=0.433 kV)	0.910 (V_A=0.394 kV)	0.977 (V_A=0.423 kV)
22 (V_B=0.433 kV)	0.887 (V_A=0.384 kV)	0.965 (V_A=0.418 kV)
23 (V_B=0.433 kV)	0.887 (V_A=0.384 kV)	0.965 (V_A=0.418 kV)

Here, V_A is Actual Voltage and V_B is Base Voltage.

- The bus connected to Power Grid gets continuously loaded except during Power Grid failure condition.
- The load connected to Power Grid is highest when future load expansion is considered as all load points along with spare are continuously supplied by power through main transformer.
- The load connected to Power Grid is medium during abnormal conditions as all critical load points are continuously supplied by power either through main transformer or backup transformer until all transformers fail.
- During all Transformer Bay failures, the critical load points are supplied through corresponding DG set and thus there is zero load connected to Power Grid in that condition.
- The theoretical calculations are matching with the practical results.
- The voltage drop magnitude across the branches is less than 5% which is the permissible value. It is 0-1.5% for cables and 0-2.5% for Transformers as the ratings of equipments.
- During different conditions, total generation, loading and demand have the values between the range of 1-12 MW and the generation is able to fulfill the critical load demand in every condition.
- The Capacitor banks are able to maintain the Power Factor of the system during all conditions above 85% lagging which is the permissible value which indicates that losses in the system will be less, within the limit.
- System voltage profile is maintained within standard limits i.e., 0.95-1.05 per unit volts in every condition.
- The load flow calculation for the all purposed designs is completed in maximum 3 iterations.

4. CONCLUSION

The typical chemical industry existing and proposed electrical distribution system has been designed and analyzed using ETAP software and the load flow results are shown in graphs. The results show that the proposed distribution system has less voltage drop, less losses, improved power factor and hence improved voltage profile in comparison to the existing distribution network with extended load due to the change in capacitor bank ratings, transformer ratings, circuit breaker ratings, cable ratings, DG set ratings and bus-bar ratings as per the requirement. This case study provides better understanding of actual condition of connected industrial load and it gives knowledge about load flow in distribution system.

REFERENCES

[1] D.L.Beeman, and R.H.Kaufmann (1942) "The Fundamentals of Industrial Distribution Systems" *AIEE TRANSACTIONS*, Vol.61, pp.272-279.

[2] C.J.Soni, P.R.Gandhi, and S.M.Takalkar (2015) "Design and Analysis of 11KV Distribution System using ETAP Software" *IEEE CONFERENCE*, pp.451-456.

[3] Z.Cramer, M.Y.Vaziri, and M.Zarghami (2015) "Distribution Substation Bus Design for Optimal Reliability and Economics", *IEEE CONFERENCE*, pp.1-4.

[4] Ali.A.Radwan, Medhat.O.Foda, Abo-Hashima, and Yehya.S.Mohamed (2017) "Modeling and Reconfiguration of Middle Egypt Distribution Network", *IEEE CONFERENCE*, pp.1258-1264.

[5] Meenu Jayamohan, Drisya.K.P, Bindumol.E.K, and Babu.C.A. (2016) "Improved BFSA for Computation of Power loss and Voltage profile in Radial Distribution System", *IEEE CONFERENCE*, pp.3247-3250.

[6] Biswajeet Rout and Naran.M.Pindoriya (2018) "Active Distribution Analysis - A Case Study", *IEEE CONFERENCE*, pp.828-833.

[7] Satish Saini, M.P.Sharma, Bhavesh Vyas and Manoj Gupta (2016) "A Case Study for Loss Reduction in Distribution Networks using Shunt Capacitors", *IEEE CONFERENCE*, pp.1-6.

[8] New Yin, Myint Thuzar and Ei Phyo Thwe (2017) "Analysis of Loss Reconfiguration for Distribution Network System", *IEEE CONFERENCE*, pp.299-302.

[9] Rana.A.Jabbar Khan, Muhammad Junaid and Muhammad Mansoor Asgher (2009) "Analysis and Monitoring of 132kV Grid using ETAP Software", *IEEE CONFERENCE*, pp.113-1180.

[10] Abeer Oun, Ibrahim Benabdallah and Cherif Adnene (2018) "Analysis and Design of a Grid Connected Real Plant in Libya using ETAP Software" *IJCSNS*, Vol.18, No.3, pp.31-40.

[11] Metha V., Metha R. (2006) *Principles of power system*, S. Chand Publications, pp. 41-126, 356-585.

[12] Satnam P. and Gupta P. *Substation Design and Equipment*, Dhanpat Rai Publications, pp.1-16.

[13] ETAP®16.0 Software Manual and Tutorials