International Journal of Control, Energy and Electrical Engineering (CEEE)
Vol.7 pp.50-56

# Power flow and Short circuit with different load and contingency scenarios of an electrolysis plant

Amine Zeggai
Irecom laboratory, dept. of electrotechnics
UDL university of Djilali Liabes , Sidi Bel Abbes, Algeria
zeggai-amine13@hotmail.com

Farid Benhamida
Irecom laboratory, dept. of electrotechnics
UDL university of Djilali Liabes , Sidi Bel Abbes, Algeria
farid.benhamida@yahoo.fr

***Abstract*—This This paper presents a power flow and voltage profile analysis of an electrolysis plant power system with a power supply of 30 MW and a distribution level of 63 kV / 20 kV/ 5.5 kV / 0.4 kV and a 5 MVA steam turbine at the 5.5 kV level. The purpose of the simulation is to predict the behavior of a real system of an HV customer through the power flow and the short circuit with different load and contingency scenarios in order to know and to control its operation, the simulation is carried out using Electrical Transient Analyzer Program (ETAP). The effectiveness of results are proven by comparison to hand calculation and real measures taken in electrolysis plant.**

***Keywords*— Load Flow Analysis, electrical Transient Analyzer Program (ETAP), Real Industrial Enterprise, Short circuit Analysis, Different load scenarios.***

## I. Introduction

Large industrial process plants like oil and gas, fertilizers and petro-chemical etc. needs electrical as well as steam energy. These plants demand high reliability as well as economic costs for power and steam generation. In many areas where reliable power is costly or difficult to access, these industries have developed their own captive power plants to meet their needs. This increases the complexity of industrial power systems due to distributed generation and grid interconnection. The power system deployed must be capable of meeting the load requirement under defined contingencies. To monitor, to maintain stability under various operating conditions and to manage these complex industrial power systems, different additional sophisticated simulation software's are used. To facilitate the supply of reliable power, operation team needs to create different scenarios for power flow, short circuit and stability studies in advance to check the constrains in the system, if any. Proactive actions can be taken based on these simulation study results to minimize disruption to process plant operations. A continual and comprehensive analysis of a power system is required to evaluate current status of the system and to evaluate the optional plans for system expansion[1].

Electrical power system in large-scale industry has inherent discrimination in itself as far as the system is concerned. In addition, sizes of power source and load are large; considering its complexity of power generation is the same as other power generation of electrical power system. Large numbers of medium and low-voltage motors are considered. Due to electrical power system of the whole plant involving with the requirements of power source, distribution network, a great deal of motor loads, manufacturing and technical management, it is higher than power supply companies in medium-sized industry under controlled conditions [2] [3].

The power system model of an industrial complex is presented here uses NR method based power flow analysis (1) simulation using ETAP software version 16.0.0. The acceptable voltage limits are as per the standard IS-12360-2006.The power flow simulations are carried out for identifying best operating conditions provided under the guidelines of process requirements, and (2) simulation of short circuit analysis to check the rating of electrical devices under fault condition and to establish the fault levels of the system at various voltage levels for various operating conditions of the plant the effect of 3-phase, line-to-ground, line-to-line, and line-to-line-to-ground faults on electrical distribution systems. The program calculates the total short circuit currents as well as the contributions of individual motors, generators, and utility ties in the system. Fault duties are in compliance with the latest editions of the ANSI/IEEE Standards (C37 series) and IEC Standards (IEC 60909 and others).

The ETAP software performs numerical calculations of large integrated power system with fabulous speed besides generating output parameters.

## II. NETWORK DETAILS

The power supply of an electrolysis plant is from the Algerian electricity company (Sonelgaz) 220/63 kV source station located about 3 km away. From the Sonelgaz substation, two 63 kV lines supply two 63 kV / 20 kV, 39 MVA step-down transformers each

The main Factory Unit is divided to six principal zone:


ISSN 2356-5608

- **Zone 1** (Central): supplied by (1) two 20 kV / 5.5 kV, 5 MVA transformers, one transformer operated in emergency, (2) two 5.5 kV / 380 V, 2.5 MVA transformers, one transformer operated in emergency and (3) a 380/380 V, 400 kVA transformer for lighting.
- **Zone 2** (Lixi-purif): supplied by (1) two 20 kV / 380 V, 2.5 MVA transformers with one transformer operated in emergency and (2) a 380/380 V, 400 kVA transformer for lighting.
- **Zone 3** (Electrolysis): supplied by (1) two 20 kV / 380 V, 2.5 MVA transformers with one transformer operated in emergency and (2) a 380/380 V, 400 kVA transformer for lighting.

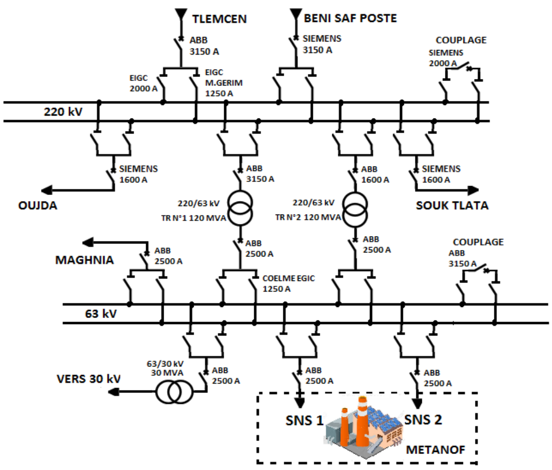

Fig. 1. Single line diagram GHAZAOUET 220/63/30 kV

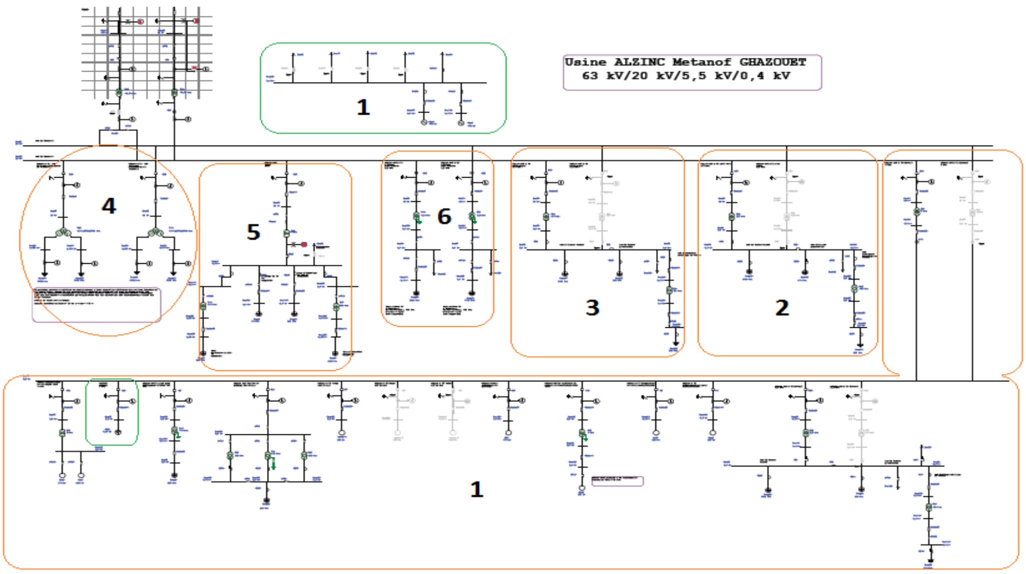

Fig. 2. Distribution network of electrolysis plant

- **Zone 4** (Zinc Electrolysis): supplied by two rectifiers connected in series with two 20 kV / 380 V, 11.1 MVA transformer.
- **Zone 5** (Refonte): two furnaces are supplied by two 20 kV / 225, 330, 350,400, 450, 500, 550, 600 V, 1.2 MVA transformers.
- **Zone 6** (Zamac): four furnaces supplied by a 20 kV / 380 V, 1 MVA transformer.

The electrolysis plant contain three generators:

- **Zone 1** (Central):
  - Two identical diesel group 1100 kVA, 380 V, 1590 A, %PF = 70, 50 Hz.
  - Steam turbine 5 MVA, 5,5 kV, 535 A, 50 Hz.

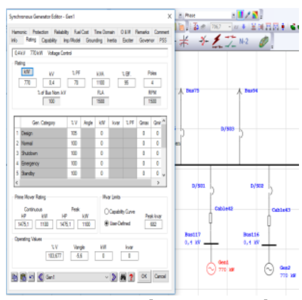
Fig. 3.Two Diesel group 1100 kVA

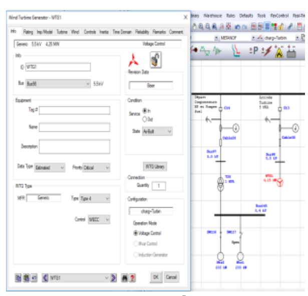
Fig. 4. Steam turbine 5 MVA


ISSN 2356-5608

## III. TEST CASE STUDY

### A. *Methodology*

Electrical system network data is modeled in the software for system analysis. Important inputs to an effective system study are:

Identification of all loads specifically split of motive and non-motive loads.

- Power sources, including voltage and short circuit levels and their operational constrains.
- Bus, Nominal kV, Initial/Operating Voltage (Magnitude and Angle), Diversity Factors (Maximum and Minimum), FDR Tag, and Equipment Name and Description.
- Generators, including MVA, voltage, impedances and grounding methods.
- Transformer sizes, their ratings, tap ratios, voltages, impedances, connections and grounding methods.
- Protective devices and their ratings.
- Length, number of conductors per phase, Sizes and types of overhead lines and underground cables.
- Future planned additions / provisions.
- Grid interconnection provision.

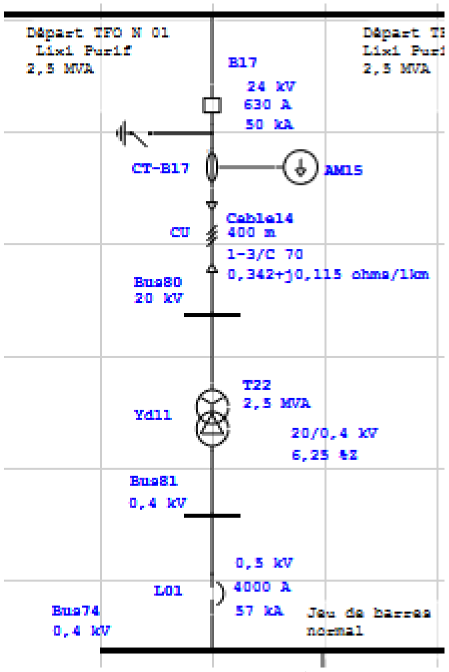


Fig. 5. Departure N° 01 of Zone 2

### B. Assumptions & Operating conditions for Power Flow study

Following are the assumptions and network operating conditions for the simulation and analysis carried out.

Load flow calculations are based on Newton Raphson method.

- ❖ **Low Load:** the company is on standby for maintenance or rehabilitation for example, the majority of the loads is stopped except the lighting, the catch, the furnace inductor... ex and all its consumption through the networks sonelgaz line 63 kV
- ❖ **Full Load**: the factory operates normal all the areas in service and all its consumption through networks sonelgaz line 63 kV.
- ❖ **Full Load + Steam Turbine** : the plant normally operates all areas in service and its consumption through the 63 kV line sonelgaz networks with a power of 5 MVA from the steam turbine that inject into 5.5 kV bar set which can supply little power to any Zone 1
- ❖ **Diesel Group (normal switch-off 63 kV):** In this case, the diesel group feed only the 400V priority bus bar of each zone (induction furnaces, lighting, capacitor batteries, etc.)

**Note:**

- ○ A steam turbine is a machine that recuperates the thermal energy of the pressurized steam in the main furnace boiler elements (the temperature at which the blende is roasted oscillates between 950 ° C and 980 ° C, This gas is cooled in the boiler up to 315 ° C) and uses it to produce a mechanical work of rotating the output shaft and transferring electrical energy through the alternator.
- ○ charge controller (63/20 kV transformer ) is a device for adding or removing turns to the main winding of the transformer can thus be adapted to the load conditions on the network to maintain the voltage at an optimal level at 20 kV bus bar

Voltage tolerences

Table I lists the voltage tolerances as per IS 123602006.

### C. General Description of Calculation Methodology

In IEC short-circuit calculations; an equivalent voltage source at the fault location replaces all voltage sources. A voltage factor c is applied to adjust the value of the equivalent voltage source for minimum and maximum current calculations. All machines are represented by their internal impedances. Transformer taps can be set at either the nominal position or at an operating position, and different schemes are available to correct transformer impedance and system voltages if off-nominal tap setting exists. System impedances are assumed to be balanced 3-phase, and the method of symmetrical components is used for unbalanced fault calculations. Zero sequence capacitances of transmission lines, cables and shunt admittances can be considered for unbalanced fault calculations (LG and LLG) if the option in the study case is


ISSN 2356-5608

selected to include branch Y and static load. This means that the capacitances of static loads and branches are considered based on IEC 60909-0 2001. Calculations consider electrical distance from the fault location to synchronous generators. For a far-from generator fault, calculations assume that the steady-state value of the short-circuit current is equal to the initial symmetrical short- circuit current and only the DC component decays to zero. However, for a near-to-generator fault, calculations count for decaying in both AC and DC components.

The equivalent R/X ratios determine the rates of decay of both components, and different values are taken for generators and loads near the fault.

## IV. SIMULATION OF LOAD FLOW ANALYSIS IN ETAP

The Load Flow software module can create and validate system models and obtain accurate and reliable results. It can calculate bus voltages, branch power factors, currents, and

TABLE I

RESULT COMPARISON OF POWER FLOW ACTUAL MEASUREMENT AND CALCULATION WITH DIFFERENT SCENARIOS OF REAL INDUSTRIAL ENTERPRISE LOAD SCALING

| | | *Calculation ETAP* | | | | *Actual Measurement* | | | |
|---|---|---|---|---|---|---|---|---|---|
| Voltage | N° bus | bus 138 0,4 kV | bus 94 0,4 kV | bus 88 5,5 kV | bus 51 20 kV | bus 138 0,4 kV | bus 94 0,4 kV | bus 88 5,5 kV | bus 51 20 kV |
| **FULL LOAD** | Voltage % | **104,3** | **101,7** | **101,9** | **100,1** | **104,34** | **102,7** | **102,1** | **100** |
| | cos(φ) | | **0,889** | | | | **0,89** | | |
| **FULL LOAD + TURBINE** | Voltage % | **104,5** | **99,72** | **100** | **100,1** | **104** | **100** | **100,1** | **100** |
| | cos(φ) | | **0,892** | | | | **0,89** | | |
| **LOW LOAD** | Voltage % | **104,5** | **102,4** | **102,7** | **100,2** | **104,78** | **102,7** | **102,1** | **100** |
| | cos(φ) | | **0,772** | | | | **0,78** | | |
| **DIESEL GROUP** | Voltage % | **105,2** | **103,4** | **/** | **/** | **105,65** | **103** | **/** | **/** |
| | cos(φ) | | **/** | | | | **/** | | |

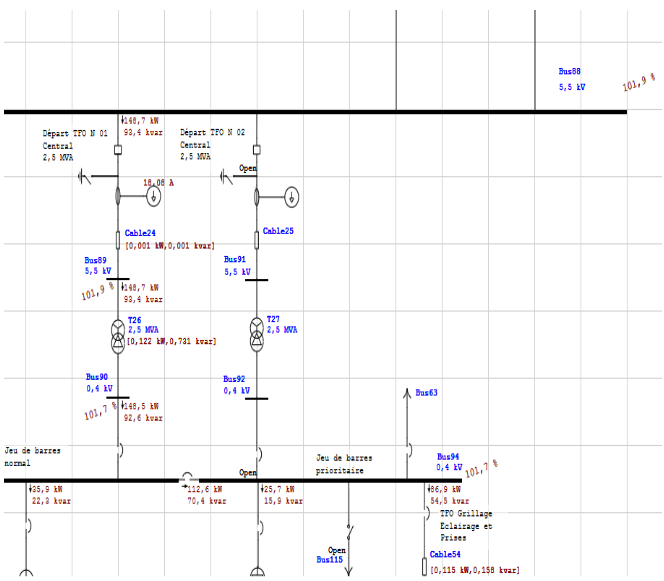

Fig. 6. Load flow analysis of full load scenario ”bus 88, 5,5 kV

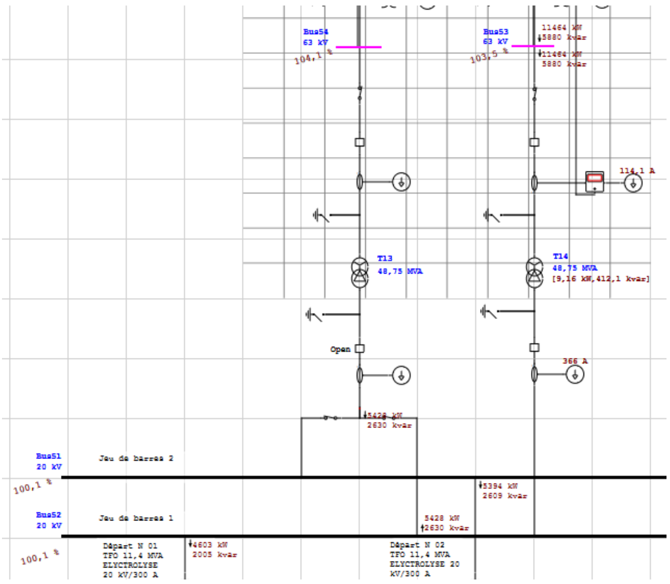

Fig. 7: Load flow analysis of full load scenario “bus 51, 20 kV”


ISSN 2356-5608

power flows throughout the electrical system.

The comparison between the result of calculation of the hand and the result of the calculation of the software ETAP is given in Table 1. It is noted that the results obtained by ETAP is precise and fast compared and we lose time in the calculations with a lack of precision. The coordinated relay protection modules and the ETAP software insertion errors are used to check the sequence of the relay protection motion sequence. The protective movement conditions of typical lines, power lines and typical equipment (large transformer and motor) are selectively checked.

It is noted that in this plant (24/24 H operation) there is no voltage drop which disrupts the quality of the electrical energy and its normal operation because there is different sources (a normal arrival and an emergency 63 kV, steam turbine 5 MVA, 2 diesel group 1100 KVA) and load regulator with relays which ensure a low voltage at all times and place. **Low load:** (20% of the load consumption "zone 1, 2, 3, 5 and 6") the FP is low 74% <in relation to load is more inductive (motor, furnace with induction, lighting, welding station...). **In charge:** the PF is increased by 89% when the zone 4 "Zinc Electrolysis" (zone in operation) is put into operation, which consumes a large power of approximately 60% of the total power.

**In charge with Turbine:** The PF remains 89% ± 1% in the case of the commissioning of the Turbine which can supply the whole zone 1 "central" which has a power factor the same (89% in charge) therefore no change.

**Diesel group (normal switch-off 63 kV):** In this case the diesel groups only supply the priority bar set in 400V (induction furnaces, lighting, capacitor batteries, etc.) with a voltage setting of 105% to avoid voltage drop in case of an increase Of the load.

Fast security assessment is of paramount importance in a modern power system to provide reliable and secure electricity supply to its consumers. To perform the contingency screening, which is one of the most CPU time-consuming tasks for on-line security assessment, the computation in a few minutes of many LF scenarios is required simulating the occurrence of several contingencies and different loading conditions

## V. SIMULATION OF SHORT CIRCUIT ANALYSIS IN ETAP

ETAP's short circuit analysis software can achieve device duty calculations which allow the determination of fault currents and comparison with manufacturer ratings. Overloaded device alarms are displayed on the one-line diagram and study reports.

**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 |
| Bus75 | 0.400 | 55.326 | 126.345 | 53.667 | 0.000 | 0.000 | 0.000 | 0.000 | 47.914 | 109.418 | 47.914 | 47.914 | 47.914 | 109.418 | 47.914 | 47.914 |

| | | 3-Phase | L-G | L-L | L-L-G |
|---|---|---|---|---|---|
| Initial Symmetrical Current (kA, rms) | : | 55.326 | 0.000 | 47.914 | 47.914 |
| Peak Current (kA), Method C | : | 126.345 | 0.000 | 109.418 | 109.418 |
| Breaking Current (kA, rms, symm) | : | | 0.000 | 47.914 | 47.914 |
| Steady State Current (kA, rms) | : | 53.667 | 0.000 | 47.914 | 47.914 |

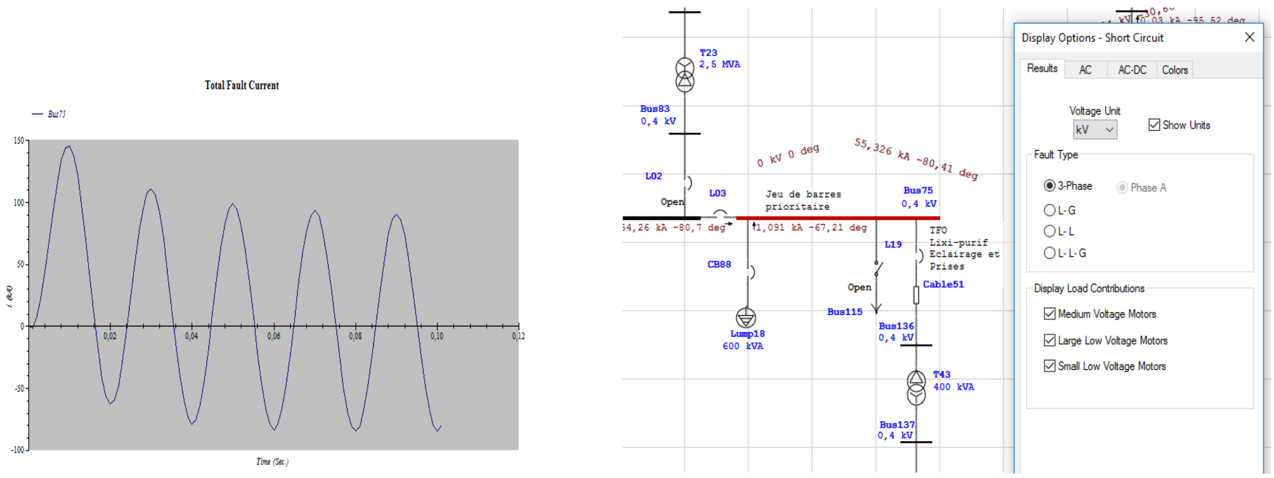


Fig. 8. 3-Phase Fault, bus 75/ 400 V with medium load scenarios

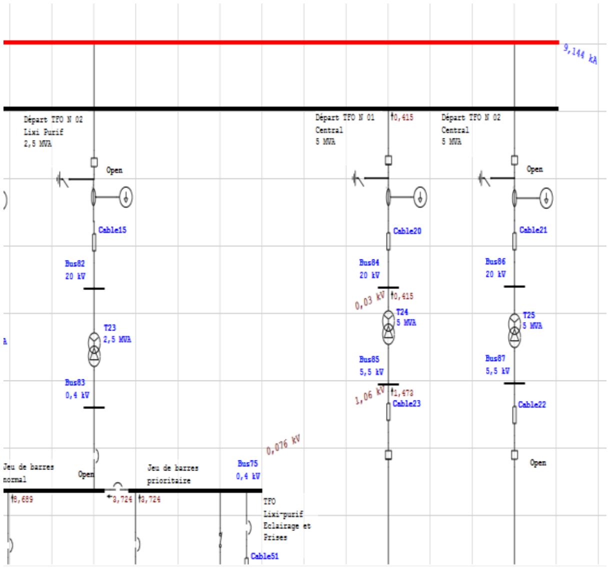

Fig. 9: Short circuit analysis "bus 51, 20 kV" with medium load scenarios

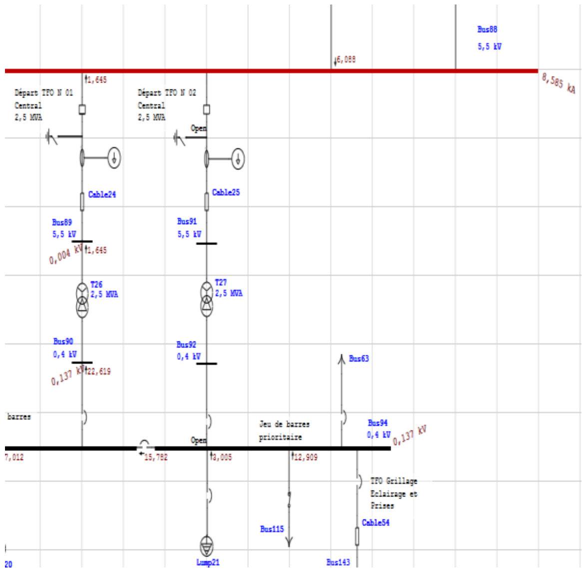

Fig. 10: Short circuit analysis "bus 88, 5,5 kV" with medium load scenarios

TABLE III.

SHORT-CIRCUIT COMPARISON OF HAND CALCULATION RESULT AND ETAP CALCULATED RESULT WITH MEDIUM LOAD SCENARIOS

| Icc | At 20 kV | At 5,5 kV | At 400 V Zone 01 | At 400 V Zone 02 | At 400 V Zone 03 | At 400 V Zone 04 | At 400 V Zone 05 |
|---|---|---|---|---|---|---|---|
| Device | 50 | 50 | 57 | 57 | 57 | 50 | 50 |
| Fault Current (KA) | 9,144 | 8,585 | 49,348 | 54, 149 | 54,422 | 22,867 | 31,957 |
| Manu Cal (KA) | 8,5 | 8,5 | 45 | 48,7 | 48,7 | / | / |

TABLE IV.

SHORT-CIRCUIT COMPARISON OF "BUS 88, 5,5 kV" WITH DIFFERENT SCENARIOS OF REAL INDUSTRIAL ENTERPRISE LOAD SCALING

| Bus 88 5,5 kV | 3-Phse fault (kA) | Line to Grount fault (kA) | Line to line fault (kA) | Line to line to Grount (kA) |
|---|---|---|---|---|
| **LOW LOAD** | 6,891∟-80,91 | 0 ∟ 0<br>0 ∟ 0<br>0 ∟ 0 | 3,445 ∟ -81,85<br>3,445 ∟ 98,15<br>0 ∟ 0 | 3,445 ∟ -81,85<br>3,445 ∟ 98,15<br>0 ∟ 0 |
| **FULL LOAD** | 7,836∟-80,91 | 0 ∟ 0<br>0 ∟ 0<br>0 ∟ 0 | 3,887∟-81,05<br>3,887∟98,95<br>0 ∟ 0 | 3,887∟-81,05<br>3,887∟98,95<br>0 ∟ 0 |
| **FULL LOAD + TURBINE** | 10,855∟-82,57 | 3,25∟-81,91<br>3,25∟-81,91<br>3,25∟-81,91 | 5,437 ∟ -82,22<br>5,437 ∟ 97,78<br>0 ∟ 0 | 6,905∟-82,25<br>3,964∟97,56<br>2,94∟98,01 |


ISSN 2356-5608

The power system operations are balanced during normal operating conditions. Under irregular condition (fault) the system becomes unbalanced.
The sample short circuit analysis with ETAP is provided in Table 3. The short circuit analysis reveals a clear idea about the system under short circuited conditions and it is helpful in power system estimation. This analysis is very significant when applying relay coordination in the distribution system because it helps to determine the maximum current during the fault to determine the breaking and closing powers of the devices as well as the electromechanical and thermal behavior of the devices equipment and calculate the protection relay settings and the fuse ratings, in order to ensure good selectivity in the electrical network

REFERENCE FOR RELAY CO-ORDINATION

Relay co-ordination plays an important role in the protection of power system. For proper protection, proper coordination of relays with appropriate relay settings is to be done. Relay settings are done in such a way that proper co-ordination is achieved along various series network. However the review of Co-ordination is always essential since various additions / deletion of feeders and equipments will occur after the initial commissioning of plants. As power can be received from generators of captive power plant, the analysis becomes complex. So this study can be a base reference for relay as well as circuit breaker ratings and plug setting of the protective devices.

## VI. CONCLUSION

To evaluate various operating states of an existing system, the power flow analysis is essential and short circuit studies are important for planning future expansion of power systems as well as in determining the best operation of protective systems. In order to know how to operate a real system of a HT customer, we simulate the power flow and the voltage profile with different load and contingency scenarios using ETAP software (Electrical Transient and Analysis Program) in order to detect weak points and find the solution, in the form of an application suite consisting of a network editor, analysis modules and customizable template libraries

ETAP Load Flow software performs power flow analysis and voltage drop calculations with accurate and reliable results. . Load flow studies determine if system voltages remain within specified limits under various contingency conditions, and whether equipment such as transformers and conductors are overloaded. This can be used to determine the optimum size and location of capacitors to surmount the problem of an under voltage. Short circuits studies are the most required in a power system in order to adequately size the devices, so that they are capable to handle the short circuit currents. Also these studies provide information regarding the intensity and the probable damage which can be caused in the event of the short circuit

These studies also help to adequately design the protection system. And, equally important, short circuit study is the prerequisite for Relay Co-ordination and Arc Flash Studies.

## REFERENCES

[1] Smita Acharya, Pragati Gupta, M.A.Mujawa, “Power Flow Analysis Of A Continuous Process Plant: (A Case Study)” International Journal of Electrical, Electronics and Data Communication, ISSN (p): 2320-2084

[2] Tang Chunhua, “Electrical Power System And Simulation Of Large-Scale Industrial Enterprise,” International Conference On Advanced Power System Automation And Protection, 2011,pp. 2076-2081

[3] K. B Shah, S. K Rathor, Rohan Mehta, “ Industrial Grade Power System Study Analysis,” International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), 2016,pp. 3955-3960.

[4] Tsai-Hsiang Chen, M.S. Chen, W.-J. Lee, Peter Van Olinda ” Distribution system short circuit analysis-A rigid approach” Power Industry Computer Application Conference, 7(1):22-28 · June 1991

[5] Muhammad Naveed Malik, Ateeb Iftikhar Toor and Muhammad Asim Siddiqui, Nusrat Husain and Akif Nadeem “Load Flow Analysis Of An Eht Network Using Etap®” Journal of Multidisciplinary Engineering Science and Technology (JMEST) ISSN: 2458-940, June - 2016

[6] Guguloth Ramesh and T. K. Sunil” Optimal Dispatch of Real Power Generation Using Classical Methods“International Journal of Electronics and Electrical Engineering Vol. 3, No. 2, April, 2015,pp 115-120.

[7] R. S. Maciel, A. Padilha- Feltrin and E. Righeto, “Substitution Newton Raphson Method for the Solution of Electric Network Equations,” Transmission & Distribution Conference and Exposition: Latin America, Aug. 2006, pp. 1-6.

[8] Hui ZHU “The application of the ETAP Solftware in the Analysis and Simulation of Power Systeme” International Conference on Energy and Power Engennering, 2014, pp 209-213

[9] Ankita Palod, Vijaya Huchche “Reactive Power Compensation Using DSTATCOM” International Journal of Electrical, Electronics and Data Communication, June-2015 pp 2320-2084

[10] Mirchevski Slobodan1, Arsov Ljupcho1, Iljazi Iljaz “The Impact of Reactive Power on Energy Efficiency in Electric Drive” Conference: 13th WSEAS International Conference on Electric Power Systems, High Voltages, Electric Machines (POWER ’13), At Chania, Crete Island, Greece August 2013

[11] Kiran V. Natkar1, Naveen Kumar2 “Short Circuit Analysis Of 220/132 kV Substation By Using ETAP” International Journal of Advanced Technology in Engineering and Science. March 2016 ISSN (p): 2348 - 7550,

[12] S. Thangalakshmi ” Planning and Coordination of Relays in Distribution System” Indian Journal of Science and Technology. August 2016, ISSN (p) : 0974-5645

[13] K.Rajesh, A.Arjunamuthu, M.Karuppasamypandiyan, A.Bhuvanesh “Power Flow Analysis of 230/110 kV Substation using ETAP” International Conference on Emerging Trends in Science, Engineering, Business and Disaster Management, 2014 Feb

[14] Raj P. Load Flow and Short Circuit Analysis of 400/220 kV Substation. International Journal of Creative Research Thoughts. 2013 Apr; 1(4):1-4.

[15] Bhagyashri Patil, Swapnil Namekar ” Load Flow & Short Circuit Analysis of 132/33/11KV Substation using ETAP” nternational Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 11 (2018) pp. 9943-9952


ISSN 2356-5608