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CO-ORDINATION OF OVER CURRENT RELAYS IN RADIAL SYSTEM USING ETAP SOFTWARE

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Abstract-- power system network consists of number of circuit breakers and relays which are required to protect costly equipment. The relays in the power system have to be coordinated so as to avoid mal-operation and hence to avoid unnecessary outage of healthy part of the system. In this paper, the over-current relay coordination of 230 kV radial industrial power plant is presented using Electrical Transient Analysis Program (ETAP). It also presents load flow and short circuit analysis of radial industrial power plant using ETAP. This paper shows the star view of relays which is unique feature of ETAP for coordinating them correctly. Based up on recorded data of 230kV industrial power plant obtained from IEEE recommended practice for calculating short circuit currents in industrial and commercial power system. Results obtained are verified by manual calculation**.**

Keywords-- Generator, Buses, Circuit breakers, Relays, Current transformers, ETAP Software

I. INTRODUCTION

The demand for electrical power generally is increased at a faster rate in economically emerging countries. So the networks of electricity companies become very complicated. The exercise of load flow analysis, fault calculations and listing the primary and back-up pairs will be very tedious. In one of the linear programming method, the power system is decomposed into subsystem to give constrained matrix of diagonal structure with linking variables. The subsystem is solved using sparse dual revised simplex algorithm of linear programming. Benders algorithm for linear programming is also used to coordinate the solution for each subsystem and the master system. The linear programming method is also used to coordination of distance relay zone-2 with over-current protection.

A structured computer program that uses technically correct models, employs a user-friendly interface, uses common data base, and traps user errors is a powerful tool which greatly enhances the engineer's efficiency and productivity. ETAP is an engineering design and analysis program which satisfies these criteria. In addition, ETAP performs numerical calculations with tremendous speed, automatically applies industry accepted standards, and provides easy to follow output reports. The Electrical Transient Analyser Program, commonly known as ETAP, began as a mainframe program and was rewritten for the Picas an interactive power system analysis and design tool. ETAP, while capable of handling 1000 buses, contains a load schedule program which tracks up to 10,000,000 load items, and reports the voltage and short-circuit current at the terminals of each load item. This capability makes ETAP suitable for large industrial facilities, as well as utility systems. In this paper, we have presented industrial radial power plant model in section II.

II. SYSTEM MODEL

The industrial system is shown in below figure 1. In this system the rating of generator is 150 MW of 11KV. There are two transformers are used. Each of one is rated as 500MVA. Transformer near the generator is connected to 11 KV bus and converts the voltage into 132 KV. Transformer near the load is connected to 132 KV bus and converts the voltage into 11 KV. Data of all other ratios are based on typical data which are provided by ETAP software.

The rules of setting the over-current relays for radial system are:

A. Plug Setting: Plug setting is to be decided by considering three rules:
1. The relays shall reach at least up to the end of the next protected zone. This is required to ensure the back-up protection.

2. The plug-setting must not be less than the maximum normal load including permissible continuous overload unless monitor by under-voltage relay, otherwise the relay will not allow the normal load to be delivered.
3. In estimating the plug-setting, an allowance must be made for the fact that the relay pick-up varies from 1.05 to 1.3 times pug-settings, as per standards.

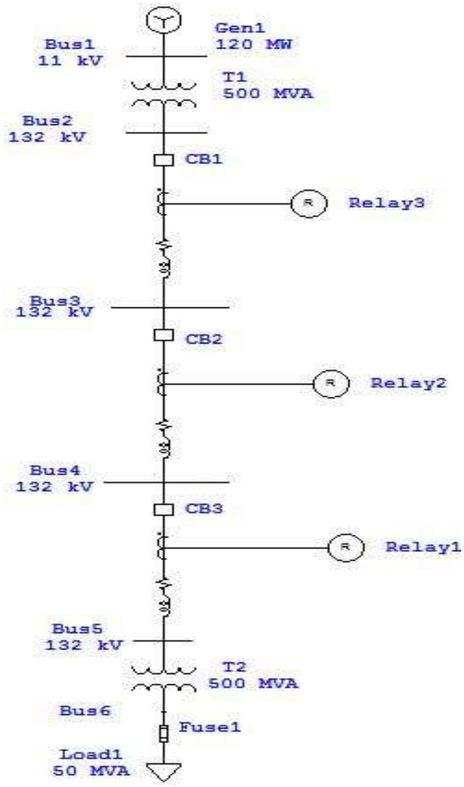

Figure 1:- Industrial Radial System

B. Time Setting:

1. The time-multiplier setting must be chosen to give lowest possible time for the relay at the end of
The radial feeder. In the preceding sections towards the source, the time multiplier should be chosen to give desire selective interval from the down-stream relay at maximum fault conditions.
2. The time multiplier setting should allow not only for the time of the breaker but also for the overshoot of the relay and allowable time errors in the time of operation of successive relays.
3. It is a common practice to use a fixed selective interval of 0.25 second (considering 2cyclebreakers) between the successive relays [3].The load flow analysis gives the current, voltage and power flow of line, bus, transformer, circuit breakers, motors and other equipment. Using the load flow study, we can decide the plug setting of relay. Same as load flow study, the short circuit study is essential to find PSM of relay. Then using this PSM, we can find the TMS of back up relay. Thus, load flow and short circuit analysis must be required in relay coordination.

Here presented load flow and short-circuit analysis of this system model using computer software ETAP. Using this short-circuits result and fault current, the relay parameters calculation is done. Then these calculated parameters are used in ETAP for relay coordination.

III. LOAD FLOW AND SHORT CIRCUIT ANALYSIS OF SYSTEM MODEL

A. Load flow analysis of industrial power plant Model using ETAP

Load flow studies are essential in the planning and operation of electrical systems. The results obtained from a load flow study (in conjunction with short-circuit study results) are used to size capacitors, feeders, transformers, and current-limiting reactors. Whether designing a new system, or analysing an existing one, factors such as voltage drop, load capacity, power factor constraints, steady-state stability limits, transformer tap settings, and generator excitation levels must be considered. In the figure 2, we present the load flow analysis of power plant model in ETAP. The voltage, active and reactive power are displayed, when we run the load flow in ETAP. This software is also capable to display the voltage in percentage or voltage or in kilovolt and also voltage drop. Same way, the active power and power angle is also shown in the place of active and reactive power. The standard output report produced by ETAP lists all input parameters on separate pages: bus input parameters, line/cable parameters, and transformer and reactor parameters. The load flow results show bus voltages, loads, generation, and power flows, as well as transformer tap setting. Equipment exposed to under voltage or overvoltage can be severely damaged and can prevent the efficient operation of machinery.

The user simply specifies the voltage or loading limits, and ETAP lists all violations in the respective summary reports. ETAP load flow output report is shown in Table I.

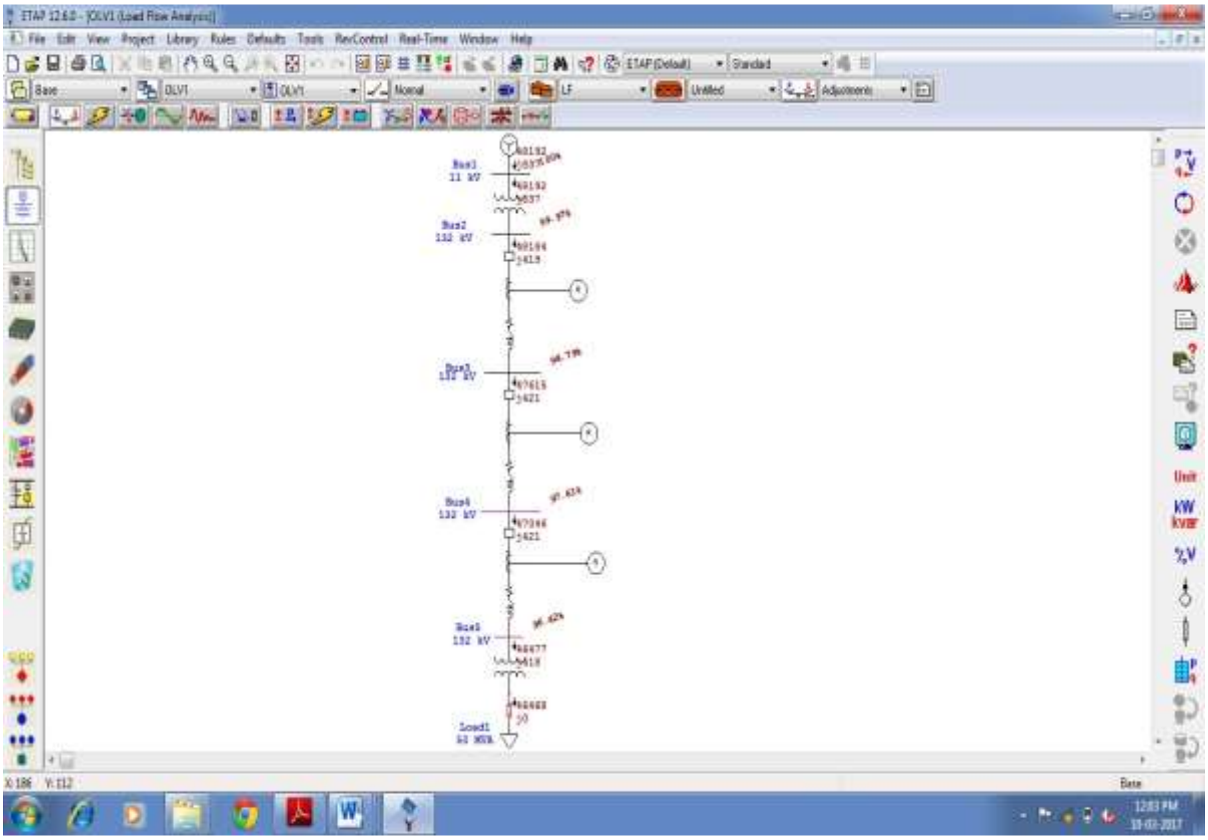

Figure 2 :- Load flow analysis in ETAP software

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
* Bus1	11.000	100.000	0.0	48.192	0.837	0	0	Bus2	48.192	0.837	2529.8	100.0	
Bus2	132.000	99.971	-0.5	0	0	0	0	Bus3	48.184	0.419	210.8	100.0	
								Bus1	-48.184	-0.419	210.8	100.0	
Bus3	132.000	98.789	-0.6	0	0	0	0	Bus2	-47.615	-0.421	210.8	100.0	
								Bus4	47.615	0.421	210.8	100.0	
Bus4	132.000	97.607	-0.7	0	0	0	0	Bus3	-47.046	-0.421	210.8	100.0	
								Bus5	47.046	0.421	210.8	100.0	
Bus5	132.000	96.425	-0.8	0	0	0	0	Bus4	-46.477	-0.418	210.8	100.0	
								Bus6	46.477	0.418	210.8	100.0	
Bus6	11.000	96.404	-1.4	0	0	46.468	0.000	Bus5	-46.468	0.000	2529.9	100.0	

Table 1:- Load flow report generated in ETAP software

B. Short circuit analysis of industrial model using ETAP

Here, the short-circuit of model and its generated report using ETAP are presented. Calculation of short-circuit currents for industrial power systems tend to be more complex because of the mixture of sources contributing currents to the fault. In a typical modern industrial system the basic sources of fault currents are the utility, the in-plant generation, and synchronous and induction motors. These sources contribute additional exponentially decaying currents which make fault current magnitudes at various locations time dependent. The report of short-circuits is presented. The short circuit view of the system in ETAP is shown in figure 3. In ETAP, the report can be generated for LLL, LL, LG, LLG LLLG (symmetrical and asymmetrical both) fault. Here, shown three phase fault is created at all buses. The short circuit report is generated as shown in Table II.

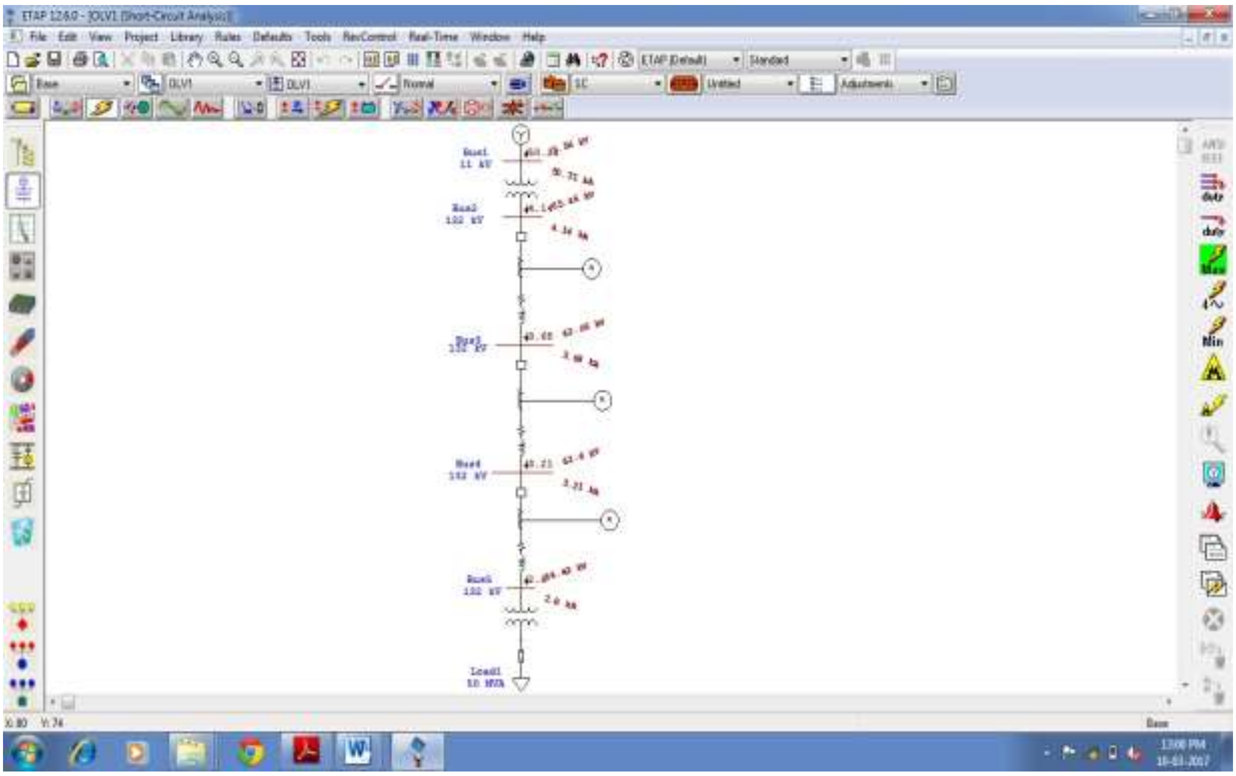

Figure 3:- Short circuit analysis in ETAP Software

SHORT - CIRCUIT REPORT

Fault at bus: **Bus1**

Prefault voltage = 11.000 kV = 100.00 % of nominal bus kV (11.000 kV)
= 100.00 % of base kV (11.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus1	Total	0.00	38.945	0.00	87.58	88.79	50.314	50.314	7.08E-001	1.35E+001	7.08E-001	4.96E+000
Bus2	Bus1	0.00	0.000	50.56	97.98	51.26	0.000	0.000				
Gen1	Bus1	100.00	38.945	100.00	100.00	100.00	50.314	50.314	7.08E-001	1.35E+001	7.08E-001	4.96E+000

Table 2:- Short circuit report generated in ETAP software

IV. RELAY CO-ORDINATION

A. Manually calculation of relay setting:

P.S.M. Calculation:

- Fault current at bus no.6 = 14.14 KA

→For Relay R_3

- CT Ratio = 1000/1
- Transformer Ratio = 132/11

→ Current at CT Primary = 14140× 11/132

= 1178.34 A

- Current at CT Secondary = 1178.34 × 1/1000

= 1.17 A

- P.S. of Relay R_3 = 117% of 1 A
- So, P.S. of Relay R_3 is selected as 125%.

→For Relay R_2

- CT Ratio = 1000/5
- P.S. of Relay R_2> 1.3/1.05 × P.S. of Relay R_3

> 1.3/1.05 × (125% of 1 A)

> 1.54 A

> 30.80% of 5 A

- So, P.S. Relay R_2 is selected as 50%.

→For Relay R_1

- CT Ratio = 1000/5
- P.S. of Relay R_1 > 1.3/1.05 × P.S. of Relay R_2

> 1.3/1.05 × (50% of 5 A)

> 3.09 A

> 61.8% of 5 A

- So, P.S. Relay R_1 is selected as 75%.

T.M.S. Calculation:

- For Relay R_3
  - →T.M.S. = 0.1 (given)
  - Actual Time of operation = T.M.S. × Approximate Time of operation

$$= \text{T.M.S.} \times 3/\log(\text{P.S.M.})$$

$$= 0.1 \times 3/\log\left(\frac{14140}{1\times1000/1}\right)$$

$$= 0.26 \text{ sec.}$$

- For Relay R_2
  - Consider discrimination time = 0.4 sec.
  - Actual time of operation = Actual Top. + disc. time Of Relay R_3

$$= 0.26 + 0.4$$

$$= 0.66 \text{ sec.}$$

  - T.M.S. of Relay R2 = $\frac{\text{Actual Top}}{\text{Approximate Top.}}$

$$= \frac{\text{Actual Top.}}{3/\log(\text{P.S.M.})}$$

$$= \frac{0.66}{3} \times \log\left(\frac{2140}{1.54\times1000/5}\right)$$

$$= 1.30$$

  - T.M.S. of Relay R2 = 1.30

- For Relay R1
  - Actual time of operation = Actual Top. + disc. Time Of Relay R_2

$$= 1.30 + 0.4 = 1.70 \text{ sec.}$$

 T.M.S. of Relay R1 = $\frac{\text{Actual Top.}}{\text{Approximate Top.}}$

$$= \frac{\text{Actual Top.}}{3/\log(\text{P.S.M.})}$$

$$= \frac{1.70}{3} \times \log\left(\frac{2270}{3.09\times1000/5}\right)$$

$$= 2.34$$

 T.M.S. of Relay R1 = 2.34.

B. Relay setting in ETAP software:

→Here considering the fault occurs near the load. Therefore first fuse protecting the load operates first then all other relay operates as backup relay. If any reason fuse does not operate then R1 operates as backup relay. In backup of R1 other two relays are also operate in ETAP software. This is shown in below figure.

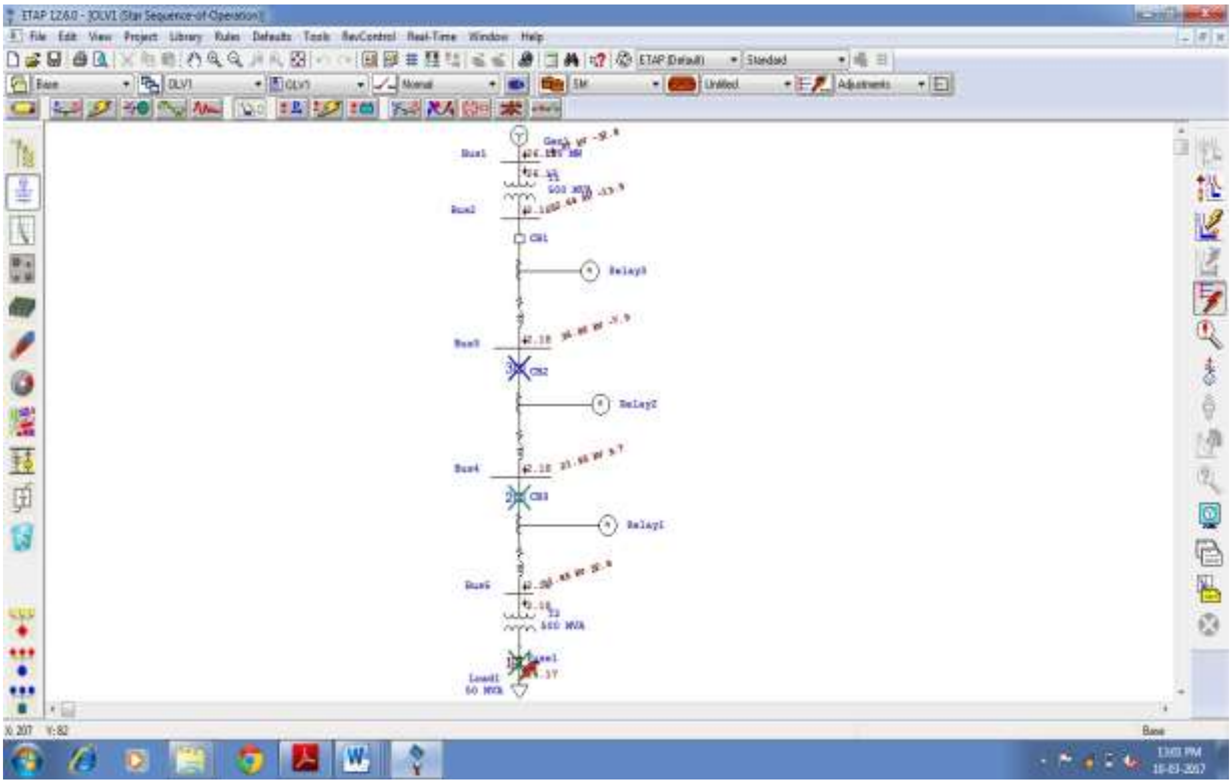

Figure 4:- Fault occurs at load side

→ Now if fault occurs at any buses or at any point on transmission line then the relay near that fault operates instantly. If any reason that relay does not operate then the backup relays are operate in sequence. Here fault occurs at bus 5 then first relay R1 operate as primary relay. If R1 does not operate because of any reason then relay R2 & R3 operate as backup relays. This is shown in below figure. Here in ETAP software in backup of primary relay, two relays operate a backup relay.

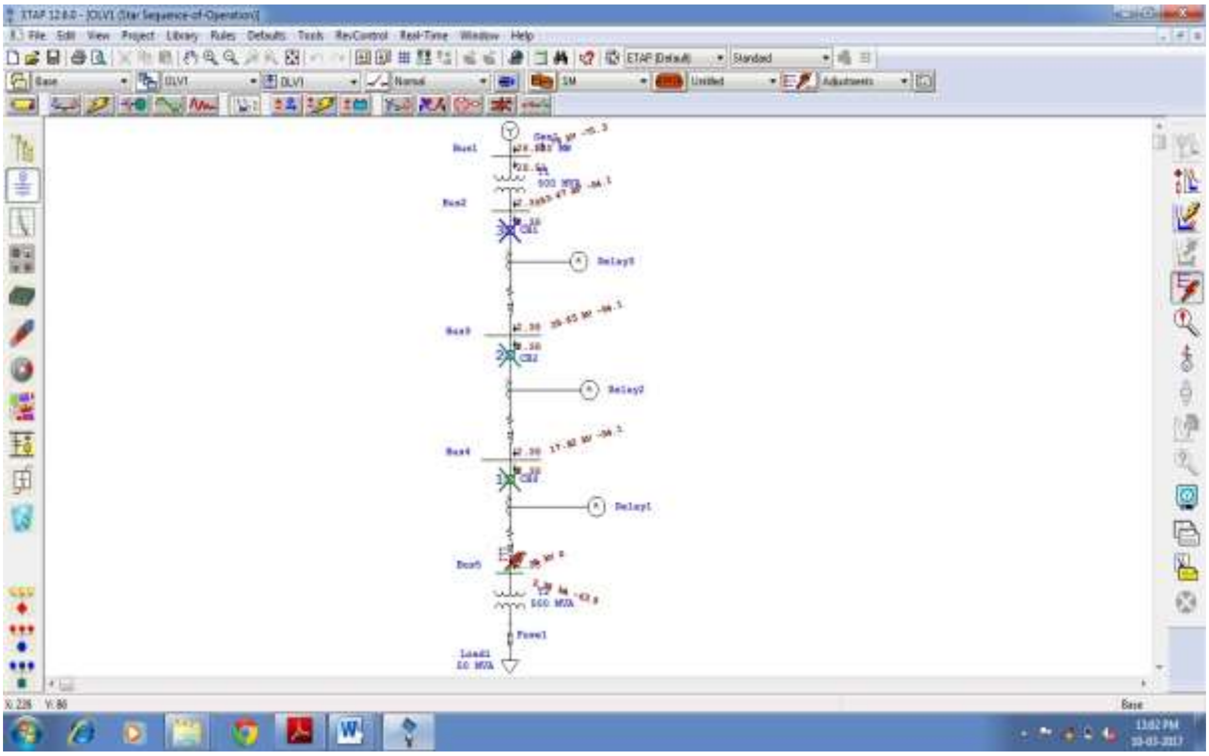

Figure 5:- Fault occurs at bus 5

ETAP has the other feature to choose the relay manufacturer and its model for protection of generator, transformer, line, feeder etc. This software has facility to show graphical representation to show the curves of each relay. And also easily drag out the relay curve to set exact coordination. If relay curve is dragging out then parameters of relay like plug setting and time dial are also changed automatically.

V. CONCLUSION

The over-current relays are the major protection devices in a distribution system. The relays in the power system are to be coordinated properly so as to provide primary as well as back up protection, and at the same time avoid mal function and hence avoid the unnecessary outage of healthy part of system. The over-current relay coordination in radial network is highly constrained optimization problem. In this paper, manual calculation of relays is presented. But, if the network is very large and complicated then it is very tedious to be done coordination of relays. So, using software like ETAP is helpful to reduce the chances of malfunction. The industrial power system is considered to illustrate. It is shown that ETAP software provides efficient tool to solve the coordination problem of over-current relays in radial system.

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