International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Comprehensive Analysis and Optimization of Radial Distribution Feeder using ETAP.

Abdul Aziz [a]*, Umar Sadique [b], Mehran Ahmad [c]

[a] Electrical *Engineering Department, The CECOS University Peshawar, Pakistan*

[b] *Computer system Engineering, UET Peshawar Pakistan*

[c] *Electronics and Communication Engineering, UET Peshawar Pakistan*

ABSTRACT

The electrical distribution system is the final and principal stage in the power system, which supplies electric power to the consumers. To respond to our distribution system is being exposed and uncovered to environmental hazards due to which faults occur. Load flow and short circuit analysis are performed on the radial distribution feeder. The paper represents a radial distribution feeder's load flow and short circuit analysis. Electrical Transient and Analysis Program (ETAP) software designs the case study (feeder). The feeder was designed in ETAP for the complete survey of the feeder, and the faults (unsymmetrical faults) were generated on different points. Those faults were then calculated mathematically using the formula, taking into account the sequence impedances of the lines (positive, negative, and zero sequences), and the calculations were performed for each fault (unsymmetrical faults). The results obtained through mathematical integration and software simulation are compared.

Keywords: Load flow; Short Circuit analysis; radial distribution system**.**

1. Introduction:

Many distribution analysis programs have recently been developed to test the unbalanced three-phase distribution. These programs use different frequency techniques and range from severe developments to some assumptions [1]

So, many computer software applications have been developed to provide load flow solutions. These methods require comparative merits and demerits concerning memory storage requirements, computation speed, and convergence criterion. Simulated and calculated. In contrast, non-technical losses are caused by secret linings, frauds in meters, low metering, and readings diversity, and many lagging in the management processes of energy [2]

Load flow is an essential tool for analysing energy systems. Different computer software development is necessary, as it is challenging to choose practical applications. Since there are many radiology distribution networks today, getting streaming solutions manually is difficult [3]. The increase in penetration of generations and the addition of voltage regulators on the distribution side lead to various challenges in load flow calculations. The complexity increases because these models are incorporated into the existing distribution load flow algorithms. In certain situations, interconnections are made in the radial distribution system such that the network becomes weakly meshed for increasing reliability. If the distribution is unbalanced, these power flow algorithms need to consider all three phases of the network. A brief review of distribution load flow is under the following categories.[4]

- Radial and Weakly Meshed SystemsUnbalanced and composite loads
- Dispersed generation
- Voltage Regulators

Practical planning of electrical distribution systems is one of the most critical research areas in electrical power systems. Due to the increasing effort and the reduction of system loss, many papers have been published in recent years indicating the optimal planning for distribution. However, in all these efforts, further study is still needed for its important sub-problem of optimising the size of the connector. Some articles have been published on the optimal planning of distribution networks and generally focused on reducing costs by raising the image of Mosul and the cost of losses. However, the increased pregnancy rate will not be reflected in almost all of these factors in future years. In addition, in most articles, there is no objective. The main goal of the electrical distribution system (EDS) is to provide a cost-effective and reliable service to consumers by considering that energy quality is acceptable to consumers. Therefore, it is necessary to plan correctly and practically for EDS and evaluate many aspects, such as equipment usage rate, the cost of installing new connectors, quality of service, loss reduction, and reliability of the distribution system, considering the increased system loads and newly installed quantities for planning [5]. Load flow study of different conductors in the electrical transient analyser program (ETAP) while considering the increasing rate of loads. A load flow study of a distribution feeder is carried out by designing the feeder from different conductors. Results obtained that include natural and reactive power flows, ampere flows, and power losses for various types of conductors are compared while bearing in mind the cost of losses and the cost of conductors, and based on these comparisons, optimal conductors for different feeder sections are selected. ETAP software is used to study the power flow of the distribution feeder.

1.1 Power Flow Analysis:

A numerical technique such as power flow analysis is carried out to analyse and evaluate the flow of electric power in an interconnected electrical system. The main objective of the power flow study is to find where the system is sensitive to the variation of power loading, conductor length, and the total capacity of the transformers used at the distribution side. The transmission and distribution system power flow study ensures the reliable, stable, and economical delivery of electrical power from generators to consumers. The primary goal of a load flow study is to investigate whether the voltage of all busbars is within the specified limits and whether the transfer of active and reactive power is reasonable to ensure that satisfactory quality of service can be provided to the consumers. The design, development, and operation of power systems require load flow calculations to analyse the static performance of the power system. The load flow studies can be completed using computer software packages specifically designed for simulation. [6].

To reduce the computational problems of load-flow solution using the load-flow iterative technique – Newton Raphson and Gauss Siedel, which are discussed in [7]The most reliable method is modelling and simulating. It should be simulated in real time, using actual data conditions to obtain the possible outcomes. [8]. The expected results will appear on each bus after running the simulation, and changes can be made to the complete layout design of the feeder to improve the weak point of the feeder by using the software for simulations. [8]We first used ETAP software to perform a power flow analysis of the distribution feeder using different conductors, such as RABBIT, DOG, PANTHER, and OSPREY, to obtain our objective.

Numerous methods, including load flow analysis, are crucial to understanding the power system. It is taken into account while evaluating the effectiveness of a power transmission network. The examination examines the system's effectiveness and the significance of various system components. To guarantee that the voltage limit is within acceptable bounds and for users to deliver an appropriate quality of service, all buses are examined for the reasonable and flexible transmission of energy. More research can be done using computer tools to analyse load profiles. [3-6].

Iterative techniques such as Newton Raphson and Gauss Seidel were discussed to reduce the computational problems of load-flow solution [7]; the most efficient way is designing a model and performing simulation. For a good simulation, the design should be on a factual basis and actual data conditions [8]. The model should operate under real-time conditions and utilise simulation software to visualise the expected outcome at each node in the design system. This allows for modifications to be made across the entire circuitry to enhance any areas of weakness.[8].

The primary goal of this thesis is to evaluate and model 220kV KV Substations using the Power World Simulator Software. This entails carrying out power flow and short circuit analyses, two crucial steps in studying and designing a power system. A model of the substation is built based on the single-line diagram of the 220 KV substations to perform the power flow analysis, and various fault types are simulated at multiple locations inside the substation. Power losses across the network, real and reactive power flows, phase angle, and other vital parameters may all be estimated with the help of the Power World Simulator Software. Additionally, short circuit analysis may help choose, arrange, and synchronise safety devices, including circuit breakers, fuses, relays, and instrument transformers. The planning and design of power systems need the use of simulation techniques. [19] The task handed to us was to construct a substation with a voltage rating of 132/33 KV. We began by employing an isolator circuit breaker-isolator combo to transmit incoming power at 132 KV to the main bus. The voltage was decreased to 33KV by a 20MVA transformer that received the electricity afterwards. From there, a 33KV bus was used to transfer the electricity to various loads. We evaluated the surge impedance loading of both the 132 KV and 33 KV lines to establish the maximum power that may be transmitted by one transmission line. All required criteria, including domestic and civil requirements, for a substation to function correctly were considered throughout the design of the whole substation. We handed the design along to our mentor for approval when it was finished. [20]

1.1.1 Feeder Sections:

The distribution department is the distribution line that makes up the entire network. Careful consideration is required since it is a critical distribution system component. Most of these lines are called feeders. The length needs to be balanced and short. Therefore, line resistance can be collected, and the effect of the ground conductor must be observed. [4]

1.1.2 Loads:

Loads can be lumped from the transformer terminals as a constant power PQ model. An equal amount of load distributed among many nodes is modelled as a distributed load. The decision of lumped or distributed loads depends on the available measurements and applications. The Loads can also be modelled as constant current, constant impedance, and voltage-dependent exponential models.

1.1.3 Sources:

The supply station is mainly considered a specified bus (slack bus). If an accurate analysis is required, the venin's impedance from the supply station is connected in series to account for the drop in the supply network.

2. Methodology

The material methodology of this system shows the load flow and transient analysis of the 11kv radial distribution feeder of city-II with the application of ETAP and mathematical analysis. First, the real-time data is collected from the PESCO office Banu of the city-II feeder. The feeder is designed using ETAP, taking the input of the data PESCO office Banu of the city-II feeder. Load flow analysis is carried out to check the power flow analysis. Faults were generated by varying loads on the bus, and many faults were generated at different lines and buses. Taking that data into account, mathematical analyses were carried out. Then, both the results were compared.

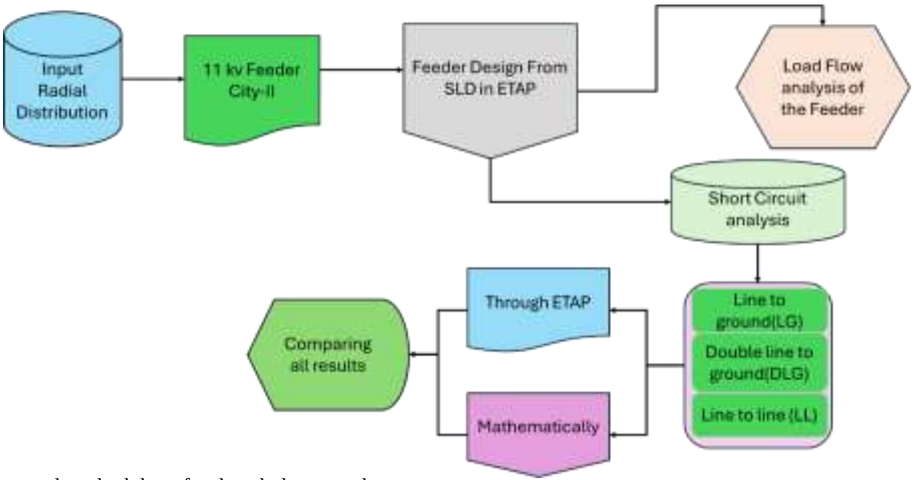

Fig.1- The proposed methodology for the whole research

2.1 subject Area

The current system under study is the city-II feeder, which is located in Banu, Kpk, Pakistan. Its 11kv feeder has a total KVA of 10065. This feeder is connected to a 132kv substation. The SLD of the case study is as follows:

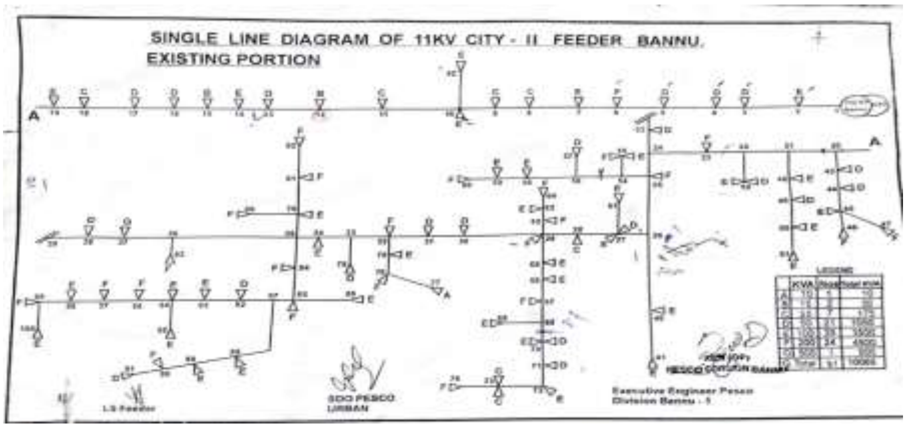

Fig 2-Single line diagram of 500 kb substation

2.2 Design of Distribution Feeder in ETAP

The feeder's single-line diagram is designed and analysed using the ETAP software.

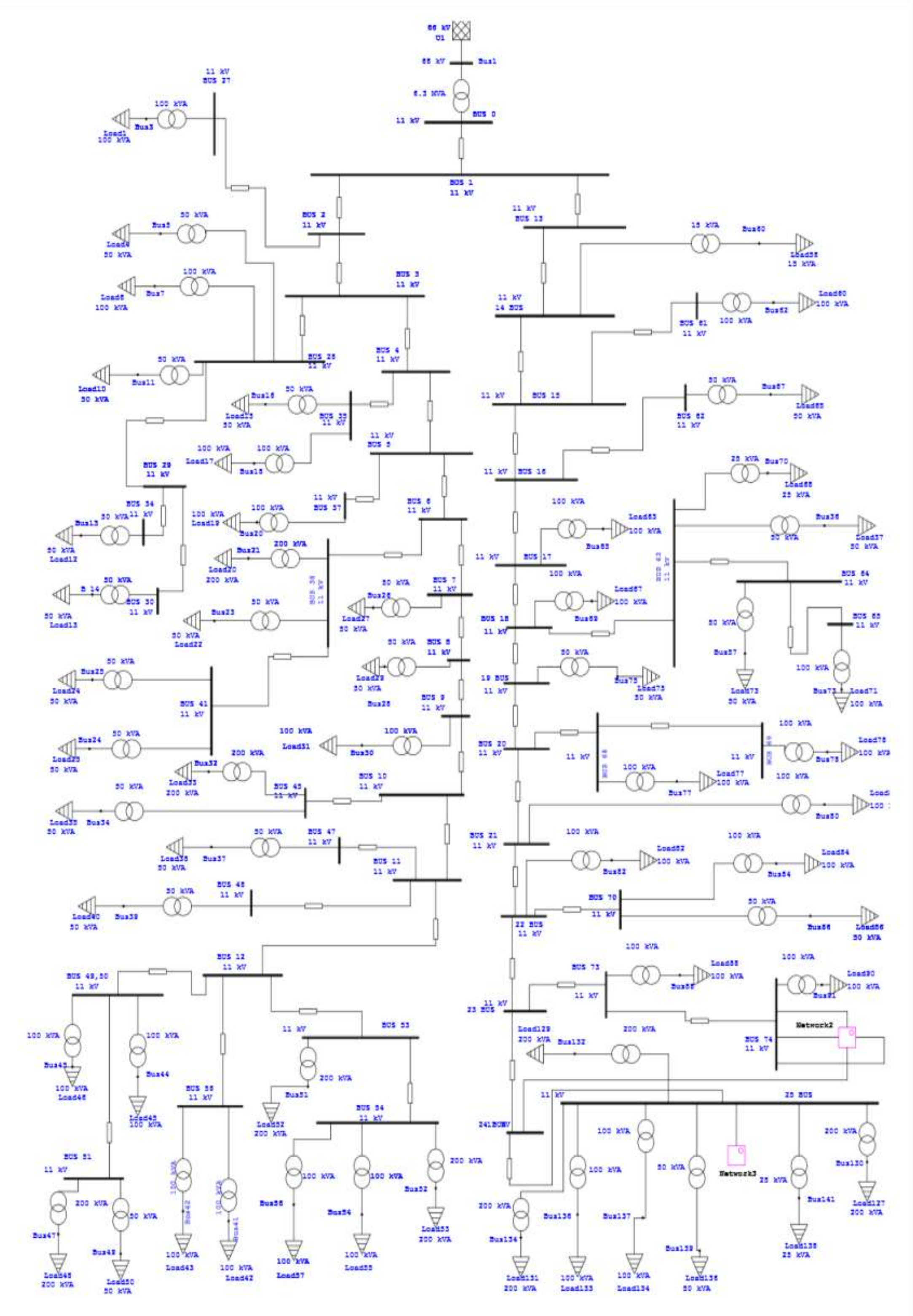

Fig. 3- Design and load flow study of an 11kV distribution feeder in ETAP.

Table 1 Feeder dada from the simulation:

	Line/Cable	Connected Bus ID	
S. No.	ID	From Bus No	To Bus No
1	Line 1-2	1	2

2	Line 2-4	2	4
3	Line 4-6	4	6
4	Line 6-9	6	9
5	Line 9-11	9	11
6	Line 11-13	11	13
7	Line 13-15	13	15
8	Line 15-17	15	17
9	Line 17-19	17	19
10	Line 19-24	19	24
11	Line 24-26	24	26
12	Line 26-28	26	28
13	Line 28-30	28	30
14	Line 30-32	30	32
15	Line 32-34	32	34
16	Line 34-36	34	36
17	Line 36-38	36	38
18	Line 38-40	38	40
19	Line 40-41	40	41
20	Line 40-51	40	51
21	Line 51-52	51	52
22	Line 52-60	51	60
23	Line 53-54	52	54
24	Line 54-46	54	56
25	Line 41-43	41	43
26	Line 43-45	43	45
27	Line 60-61	60	61
28	Line 60-65	60	65
29	Line 65-67	65	67
30	Line 67-68	67	68
31	Line 67-70	67	70
32	Line 70-71	70	71
33	Line 71-74	71	74
34	Line 71-75	71	75
35	Lin 75-78	75	78
36	Line 75-220	75	220
37	Line 78-80	78	80
38	Line 80-84	80	84

39	Line 70-86	70	86
40	Line 86-87	86	87
41	Line 87-89	87	89
42	Line 86-91	86	91
43	Line 91-93	91	93
44	Line 93-95	93	95
45	Line 95-97	95	97
46	Line 95-106	95	106
47	Line 97-99	97	99
48	Line 106-130	106	130
49	Line 130-132	130	132
50	Line 132-134	132	134
51	Line 95-149	95	149
52	Line 134-137	134	137
53	Line 149-151	149	151
54	Line 151-153	151	153
55	Line 153-155	153	155
56	Line 155-158	155	158
57	Line 158-160	158	160
58	Line 153-162	153	162
59	Line 162-165	162	165
60	Line 165-167	165	167
61	Line 167-168	167	168
62	Line 167-172	167	172
63	Line 172-174	172	174
64	Line 177-186	177	186
65	Line 167-177	167	177
66	Line 167-178	167	178
67	Line 178-182	178	182
68	Line 182-184	182	184
69	Line 186-190	186	190
70	Line 190-191	190	191
71	Line 191-193	191	193
72	Line 193-195	193	195
73	Line 190-199	190	199
74	Line 199-202	199	202
75	Line 201-203	201	203

76	Line 203-207	203	207
77	Line 201-209	207	209
78	Line 209-211	209	211
79	Line 211-213	211	213
80	Line 213-215	213	215

3. Short circuit analysis:

The world faces severe environmental pollution, climate warming, and resource depletion, and our distribution system is exposed to which faults occur.

Losses and faults always accompany the electric power supply from the generating power stations to the consumer. Very often, small loads of 100 KVA or less are fed from the same feeder in distribution systems. There are many loads connected to every feeder. During the feeder, it is spread to and covers many areas. Short circuit analysis in radial distribution systems is presented as the distribution system becomes more heavily loaded. As more sophisticated protection devices are installed, the settings of these devices can be performed remotely as needed with each change in the network, but the chance of a fault in the distribution system is still high. The process proposed in this paper calculates the short circuit current considering the loads in the system. Traditionally, short circuit analysis for power systems omits the load in the system [6]. Usually, only the path from the fault location to the root is considered. The loads have been omitted because they are thought to have a minimal effect on the short-circuit current. However, this assumption is only sometimes precise enough in the distribution system. This paper proposes to model beyond the fault path and to consider the loads in both the short-circuit current calculations and the post-fault analysis. Sometimes, the load on the transmission line increases, and the network is being faulted. The widespread and well-known faults linked with the power radial distribution system are:

- ❖ Symmetrical faults
  - Three-phase faults
- ❖ Unsymmetrical faults
  - Line to ground fault.
  - Line to line fault.
  - Double line to ground fault

The percentage of unsymmetrical faults occurring is higher than that of symmetrical faults, so here we analyse the unsymmetrical faults due to the probability of occurrence. The symmetrical fault has only further type 3-phase fault. It occurs when three phases are in contact with the ground. [5] The fault in any network drastically affects the whole network to far places. The chance of faults in the distribution system is more significant because we use a radial distribution system.

When a short-circuit occurs in a power system, the magnitude of the fault currents is very high compared to the steady state current that flows in the power radial distribution system. Symmetrical and unsymmetrical analysis of the power system network must be undertaken to determine the magnitude of these fault currents and fault MVA (Megavolt Ampere) to select adequate ratings of the power system [3]. Before discussing the fault types, we discuss the line impedance called sequence impedance here. There is their sequence impedance. Each element of the power system impedes different phase sequence components of current, which may not be the same. For example, the impedance that any piece of appliance gives to a positive sequence current would not be importantly the same as given to a negative sequence current or the current to a zero sequence. Therefore, in unsymmetrical faults during calculations, each part will have three different values of corresponding impedance, one for each sequence current.

- Positive sequence impedance (Z1)
- Negative sequence impedance (Z2)
- Zero sequence impedance (Z0)

3.1 Sequence Impedance.

3.1.1 Positive sequence impedance:

The components of the positive sequence are the 3-phasors, which have equal magnitude, a phasor angle of 120 degrees, and the same phase sequence as the originals.

$$Z_1 = r_a + (X_a + X_d)¡ \qquad (1)$$

$R = \frac{\delta L}{A}$ (2)

$X_a(f, GMR) = 1.032(\frac{f}{60}) log(\frac{1}{GMR}) \frac{\Omega}{miles}$ (3)

$X_d(f, D_{eq}) = 1.032 log(\frac{D_{eq}}{1ft}) \frac{\Omega}{miles}$ (4)

$D_e(f, \rho) = 2160 \sqrt{\frac{\rho}{f}} ft.Hz$ (5)

3.1.2 Negative sequence impedance:

The negative sequence comprises the 3-phasors with equal magnitude, a phasor angle of 120 degrees, and the same phase sequence as the originals.

$Z_2 = r_a + (X_a + X_d)$¡ (6)

$R = \frac{\delta L}{A}$ (7)

$X_a(f, GMR) = 1.032(\frac{f}{60}) log(\frac{1}{GMR}) \frac{\Omega}{miles}$ (8)

$X_d(f, D_{eq}) = 1.032 log(\frac{D_{eq}}{1ft}) \frac{\Omega}{miles}$ (9)

$D_e(f, \rho) = 2160 \sqrt{\frac{\rho}{f}} ft.Hz$ (10)

3.1.3 Zero sequence impedance:

Zero-sequence components are comprised of 3-phasors that are equal in magnitude and have 0- 0-phase displacement from each other. Using the conductor tables simplifies the calculation of zero sequence line impedances. The conductor tables provide the values of ra, Xa, and Xd. Adding the additional quantities of re and Xe provides the ground return effects. The impedance offered by an equipment or circuit to positive sequence current is called positive sequence impedance and is represented by Z1. Similarly, impedances any circuit or equipment offers to negative and zero sequence currents are called negative sequence impedance (Z2) and zero sequence impedance (Z0).

$Z_0(r_c, f, D_e, GMR) = (3.r_c + \frac{0.00477}{Hz}.f + 1j\frac{0.01397}{Hz}.log(\frac{D_e}{GMR})).\frac{\Omega}{Mile}$ (11)

$D_e(f, \rho) = 2160 \sqrt{\frac{\rho}{f}} ft.Hz$ (12)

This is because the impedance of such circuits is independent of the phase order, provided the applied voltages are balanced. MIT may note that rotating machines' positive and negative sequence impedances (e.g., synchronous and induction motors) are generally different. Zero-sequence impedance depends upon the path taken by the zero-sequence current. As this path typically differs from the path taken by the positive and negative sequence currents, zero sequence impedance usually differs from positive or negative. It is customary when solving a problem by symmetrical components to designate the three phases of the system as a, b, and c so that the phase sequence of the voltages and currents in the system is ABC. Thus, the phase sequence of the positive-sequence components of the unbalanced phasors is ABC and the phase sequence of the negative-sequence components. If the original phasors are voltages, they may be designated Va ' Vb' and Vc. Then, the additional superscript defines three sets of symmetrical components: 1 for the positive-sequence components, 2 for the negative-sequence components, and 0 for the zero-sequence components.

3.2 Line to ground fault.

When one line is in contact with the ground due to load or environmental hazards, this is an L-G fault. The power system is cut off when a single-line-to-ground fault happens in a three-phase radial distribution network, spanned as an equilateral triangle. Assume only one terminal voltage and current can be measured, as well as the diagnosis value of fault position and the diagnosis value of contact. Resistance can be calculated through the sinusoidal-steady state equation of the circuit. So, we can locate the fault according to the measuring parameters because of measuring errors, especially the phase measuring error.[7]

3.2.1 Locating line to ground fault:

The sinusoidal steady-state analysis method. By using this approach, two sinusoidal signals with different frequencies are first injected into the faulted line. The distances and resistances of all possible fault candidates can be determined by measuring some values of the voltages and currents at the sending end and solving some nonlinear radial parameter equations. A feature extraction method is derived to distinguish the actual fault from other pseudo-fault candidates. A fault locator based on the proposed approach is designed and implemented for a real-life word fault. This would be a long process and calculation. But in this paper, we accomplish how to tell the location of the fault [8].

$\vec{f} = \frac{3\vec{E_R}}{\vec{Z_1}+\vec{Z_2}+\vec{Z_0}}$ (13)

I_f =1.2222kA

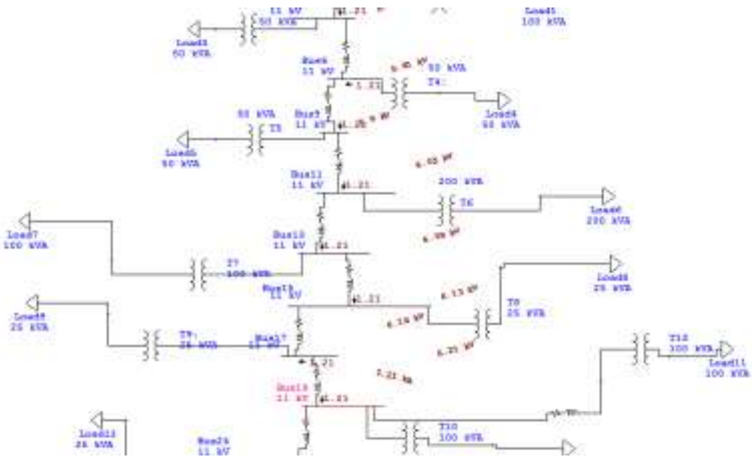

Fig.4- Feeder part where (LG) fault is generated.

3.3 Double-line to-ground fault (DLG):

When two lines short-circuit or come in contact with the ground, this type of situation is a double line-to-ground fault. The ratio of occurrence ranges from 5% to 15%. This type of faulty condition belongs to unsymmetrical faults.

3.3.1 Fault location for the double line to a ground fault:

Single line-to-earth faults may become double line-to-earth faults. In this case, determining the fault location takes a long time, as a team of experts bypasses the entire network. A method for fault location of double line-to-earth faults on different power lines of the medium-voltage distribution network is proposed. The process is implemented by determining the impedance of the line-to-earth circuit, which is proportional to the distances to each of the places of faults. [9]

$$\begin{bmatrix} Ia(0) \\ Ia(1) \\ Ia(2) \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} 0 \\ Ib \\ Ic \end{bmatrix} \quad (14)$$

$$If = I\vec{b} + \vec{I}c \quad (15)$$

$$Vb = Vc = If * Zf \quad (16)$$

$$V\vec{0} = V\vec{1} = V\vec{2} = \frac{V\vec{a}}{3} \Big) \quad (17)$$

$$I\vec{a} = I(1\vec{)} + I(2\vec{)} + I(0\vec{)} = 0\big) \quad (18)$$

$$I\vec{f} = 3I\vec{a}(0\big) \quad (19)$$

$$I\vec{f} = \frac{-3Z\vec{0}}{Z\vec{2} + Z\vec{0}} * \frac{E\vec{r}}{Z\vec{1} + \frac{Z\vec{2}Z\vec{3}}{Z\vec{2} + Z\vec{3}}} \quad (20)$$

$$I\vec{f} = \frac{-3Z\vec{2} * E\vec{r}}{Z\vec{0} * Z\vec{2} + Z\vec{0} * Z\vec{2} + Z\vec{1} * Z\vec{2}} \quad (21)$$

$$\vec{I}_F = 1.958kA$$

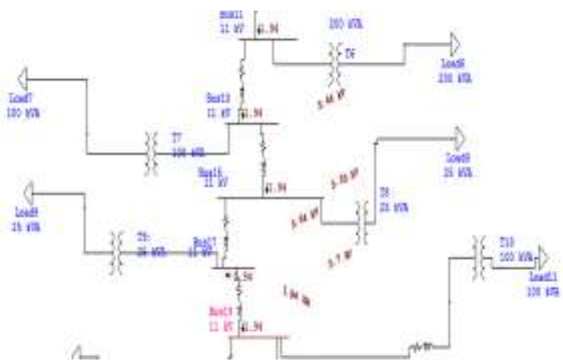

Fig.5-The part feeder where the double line to ground fault is generated through ETAP.

3.4 Line to line fault (LL);

Sometimes, due to stormy conditions, the two lines touch accidentally and come closer. This collision causes a fault to occur across the system, which is called a line-to-line fault. The current value is zero at the output end because both sequence impedances cancel each other, and the output current gets zero [16].

$$I\vec{f}=\frac{-i\sqrt{3}*\vec{E}_R}{Z\vec{1}*Z\vec{2}} \qquad (22)$$

I_{f1}=0.88kA, I_{f2}=-0.88kA

Net Current =0 kA

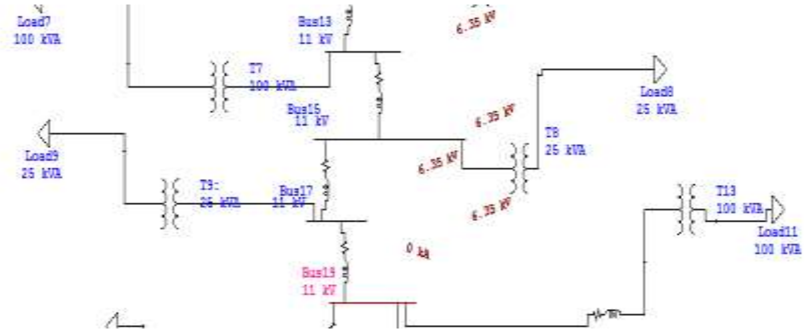

Fig.6-The part feeder where the line-to-line fault is generated through ETAP.

4. Conclusion

Electrical distribution in the power system is the main stage in supplying the consumers. The Electrical Transient and Analyzer Program (ETAP) is used for load flow and short circuit analysis. Load flow is the numerical analysis of the flow of electric power, which focuses on various aspects of AC power parameters, such as voltages, voltage angles, real power, and reactive power at each bus in the steady state and for planning and controlling a system. Our distribution system is exposed to environmental hazards due to symmetrical and unsymmetrical faults. These faults are analysed mathematically and simulated using EATP, such as line-to-ground, double-line-to-ground, and line-to-line faults. The results obtained through mathematical analysis and software simulation are being compared.

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