

Utilize Matlab To Analyse The Load Flow In Three-Phase Unbalanced Distribution Feeders.

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Abstract - The load flow solution for a three-phase unbalanced radial distribution feeder is shown in this study using the MATLAB/Simulink programme. The IEEE distribution system analysis subcommittee's approach and Simulink's load flow analysis have also been compared for a variety of topologies. The Newton-Raphson method has been applied to load flow analysis. For comparison, the IEEE 13 and 34 node test feeder models are utilised since they encompass all realistic load profiles and configurations, including single phase lateral, dispersed, and three phase asymmetric loads. Results display voltage magnitude and voltage angle at different load buses with the least amount of losses.

Index Terms— MATLAB/Simulink model, Node Test Feeders, Load Flow Analysis

I. INTRODUCTION

For the examination of unbalanced three-phase radial distribution test feeders, numerous pieces of software have recently been created [1]. These programmes employ various iterative methodologies and span from extremely simplistic line and load model assumptions to very sophisticated programmes with few assumptions. Benchmark test feeders are used to compare these software's output against. In addition to presenting a Simulink model for IEEE 13 and 34 node test feeders, this paper compares the results of Simulink's load flow model to those of the IEEE Distribution Systems Analysis Subcommittee.

In particular, distribution automation and power system optimization call for recurring load flow solutions, making load flow a crucial instrument for examination of power systems. The selection of solutions for real-world applications is challenging, necessitating the creation of numerous computer systems. Due to the enormous number of radial distribution networks that exist today and the difficulty of manually locating their load flow solutions [3], numerous computer programmes that provide load flow solutions have been developed. These techniques call for a comparison of their benefits and drawbacks with regard to memory storage needs, processing performance, and convergence criteria.

Mostly, load flow solution for balanced radial distribution networks is easily available; however, much work is not reported for unbalanced radial distribution networks.

Single phase, two phase, and three phase loads as well as asymmetrical line segment data are the main causes of the networks' unbalance. This article develops a Simulink model for the unbalanced 13 and 34 node test feeders. A load flow solution for the Simulink model is provided by the POWERGUI block. CYME [7] power engineering software, DIGSILENT power factory, and PSCAD have all been used in recent years to compare these unbalanced node test feeder configurations. However, MATLAB/Simulink have not been used in any such work.

II. THE TEST FEEDERS

Data for all the test feeders are taken from [4]. This data for feeders consists of:

Line segment Data:

A table containing line segment data including the length of the line segment and a configuration code is provided for each feeder setup. Additionally, for each line segment, it offers node terminations, or lines that connect nodes.

Load Models:

There are two types of load present in these models:

1. Spot load: Load can be connected at various nodes.
2. Distributed load: Load that is distributed along a line section.

Three-phase (balanced or unbalanced) or single-phase loads are both possible. These loads have constant kW (P) and kVAR (Q), constant impedance (Z), or constant current specifications in the models (I). Lists of codes that will be used to describe various loads are provided in Table I.

TABLE I Load Model Codes

Code	Connection	Model
Y-PQ	Wye	Constant kW and kVAr
Y-I	Wye	Constant Current
Y-Z	Wye	Constant Impedance
D-PQ	Delta	Constant kW and kVAr
D-I	Delta	Constant Current
D-Z	Delta	Constant Impedance

Shunt Capacitors:

The shunt capacitor banks are modelled as single phase line-to-line and line-to-ground three phase wye or delta systems. These capacitors' ratings are listed as rated kVAr.

Voltage Regulators:

Voltage regulators can be linked in a substation or to a specific line segment, and they are presumed to be step-type devices. The voltage regulator is replaced with three-phase generators with a constant voltage source in the MATLAB/Simulink model.

III. THE IEEE 13 NODE TEST FEEDER

Software developers and field engineers can use test systems created by the IEEE Distribution Systems Analysis Subcommittee to validate their research. Fig. 1 displays the single line schematic for the 13 node test feeder. According to the subcommittee, the 13 node test feeder has the following characteristics:

- Short and relatively highly loaded for a 4.16KV feeder
- One substation voltage regulator consisting of three single-phase units connected in wye.
- Overhead and underground lines with variety of phasing.
- Shunt capacitor banks.
- In-line transformer.
- Unbalanced spot and distributed loads.

Simulink Model:

The electrical components from the SIMSCAPE Power system were used to create the Simulink model that follows. Asymmetrical distributed lines, transformers used to step down the voltage, unbalanced three-phase loads, load flow buses, and generating sources are some of the components of this concept. The only presumption made in that model is that the voltage regulator will be replaced by a three-phase device with the same rating generators. POWERGUI tool box uses Newton-Raphson method for load flow analysis.

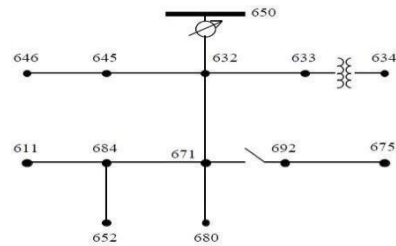


Fig. 1:Single line diagram of 13 node test feeder

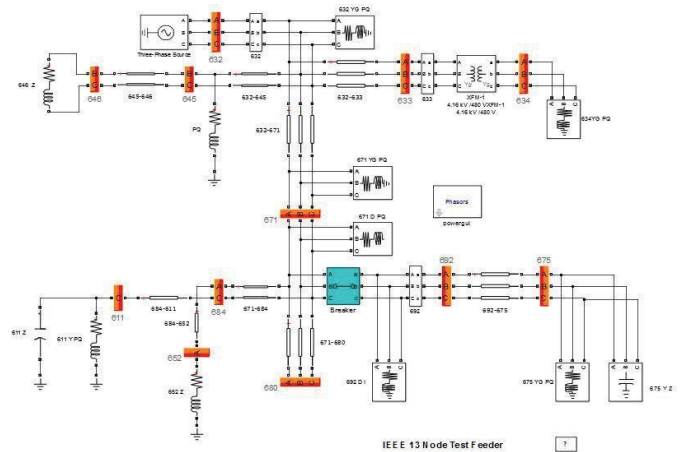


Fig 2. :Simulink model for 13 node test feeder

IV. THE IEEE 34 NODE TEST FEEDER

The one line diagram for 34 Node Test Feeder is shown in Fig. 3. Characteristics of 34 node test feeder as given by the Subcommittee are as following:

- Very long and lightly loaded.
- Two in line regulators required to maintain a good voltage profile.
- An in-line transformer reducing the voltage to 4.16 kV for a short section of the feeder.
- Unbalanced loading with both “spot” and “distributed” loads. Distributed loads are assumed to be connected at the center of the line segment.
- Shunt capacitors.

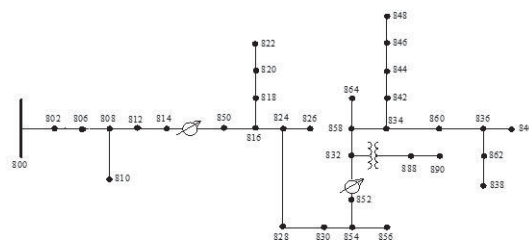


Fig.3: Single line diagram of 34 node test feeder

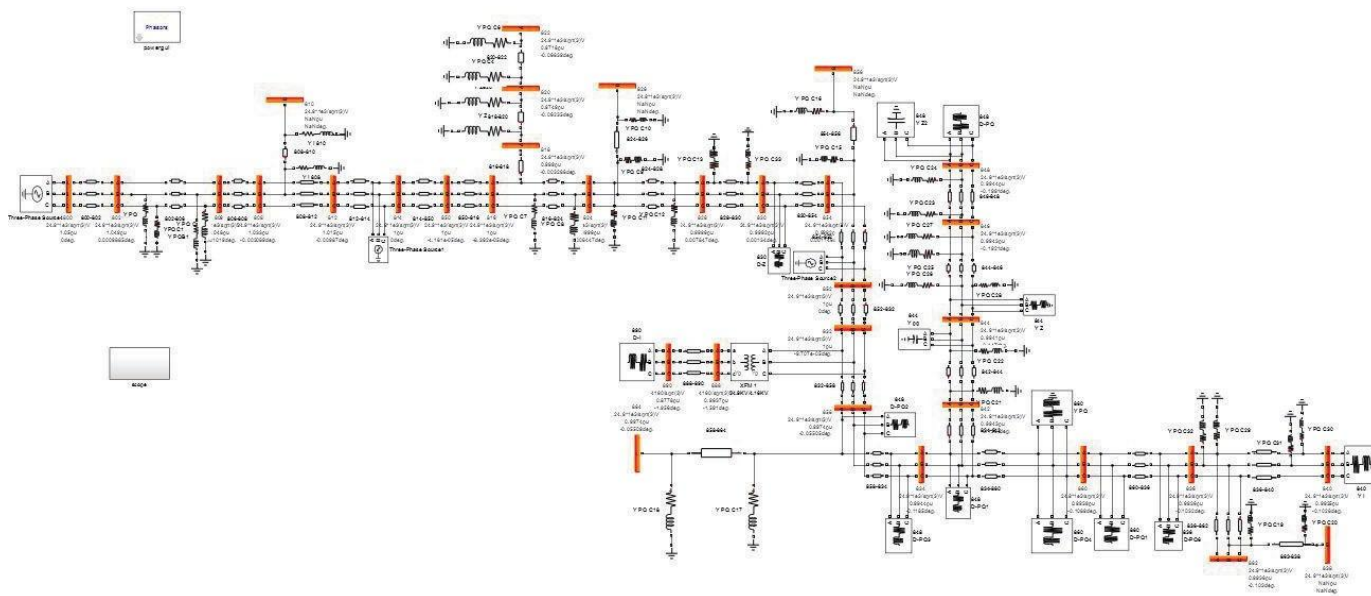


Fig.4: Simulink model for 34 node test feeder

V. COMPARISON OF RESULTS

Tables [II-III] compare the load flow analysis findings from the Simulink model with the results from the radial distribution analysis subcommittee for the 13 and 34 Node Test Feeders. For unbalanced node test feeders, the voltage magnitude and voltage angle of various phases are examined.

Bus Voltages:

TABLE II Comparison of voltages magnitude in (p.u) at various buses for 13 bus system

Bus NO.	Simulink	IEEE	Simulink	IEEE	Simulink	IEEE
	Va(pu)	Va(pu)	Vb(pu)	Vb(pu)	Vc(pu)	Vc(pu)
650	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
RG60	1.0625	1.0625	1.0500	1.0500	1.0687	1.0687
632	1.0210	1.0210	1.0420	1.0420	1.0174	1.0174
633	1.0178	1.0180	1.0402	1.0401	1.0148	1.0148
XFM1	0.9941	0.9941	1.0218	1.0218	0.9960	0.9960

634	0.9938	0.9940	1.0218	1.0218	0.9959	0.9960
645	NA	NA	1.0329	1.0329	1.0154	1.0155
646	NA	NA	1.0312	1.0311	1.0133	1.0134
671	0.9871	0.9900	1.0519	1.0529	0.9780	0.9778
680	0.9871	0.9900	1.0519	1.0529	0.9780	0.9778
684	0.9851	0.9881	NA	NA	0.9761	0.9758
611	NA	NA	NA	NA	0.9741	0.9738
652	0.9796	0.9825	NA	NA	NA	NA
692	0.9871	0.9900	1.0519	1.0529	0.9780	0.9777
675	0.9806	0.9835	1.0543	1.0553	0.9760	0.9758

Voltages Angles:

TABLE III Comparison of voltages angles at various buses for 13 bus system

Bus NO.	Simulink	IEEE	Simulink	IEEE	Simulink	IEEE
	Angle (Va)	Angle (Va)	Angle (Vb)	Angle (Vb)	Angle (Vc)	Angle (Vc)
650	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
RG60	1.0625	1.0625	1.0500	1.0500	1.0687	1.0687
632	1.0210	1.0210	1.0420	1.0420	1.0174	1.0174
633	1.0178	1.0180	1.0402	1.0401	1.0148	1.0148
XFM1	0.9941	0.9941	1.0218	1.0218	0.9960	0.9960
634	0.9938	0.9940	1.0218	1.0218	0.9959	0.9960
645	NA	NA	1.0329	1.0329	1.0154	1.0155
646	NA	NA	1.0312	1.0311	1.0133	1.0134
671	0.9871	0.9900	1.0519	1.0529	0.9780	0.9778
680	0.9871	0.9900	1.0519	1.0529	0.9780	0.9778
684	0.9851	0.9881	NA	NA	0.9761	0.9758
611	NA	NA	NA	NA	0.9741	0.9738
652	0.9796	0.9825	NA	NA	NA	NA
692	0.9871	0.9900	1.0519	1.0529	0.9780	0.9777
675	0.9806	0.9835	1.0543	1.0553	0.9760	0.9758

The load flow solution obtained by Simulink is converged in 3 iterations for 13 node test feeders. The power flow result obtained are shown in Table IV

TABLE IV Power flow solution

Location	Active Power in KW	Reactive Power in KVAR
Total generation	3518.74	1540.14
Total PQ load	3101.90	1880.42
Total Z shunt load	363.47	-479.42
Total losses	53.36	139.14

Tables [V-VI] show the comparison for 34 node test feeder of voltage magnitude and voltage angles. These configurations are used by many researchers.

Bus Voltages:

TABLE V Comparison of voltages magnitude in (p.u) at various buses for 34 bus system

Bus NO.	Simulink	IEEE	Simulink	IEEE	Simulink	IEEE
	Va(pu)	Va(pu)	Vb(pu)	Vb(pu)	Vc(pu)	Vc(pu)
800	1.0500	1.0500	1.0500	1.0500	1.0500	1.0500
802	1.0492	1.0475	1.0492	1.0484	1.0492	1.0484
806	1.0487	1.0457	1.0487	1.0474	1.0487	1.0474
808	1.0387	1.0136	1.0405	1.0296	1.0398	1.0289

810	NA	NA	1.0403	1.0294	NA	NA
812	1.0270	0.9763	1.0321	1.0100	1.0289	1.0069
814	1.0177	0.9467	1.0255	0.9945	1.0203	0.9893
RG1	1.0177	1.0177	1.0255	1.0255	1.0203	1.0203
850	1.0177	1.0176	1.0255	1.0255	1.0203	1.0203
816	1.0177	1.0172	1.0255	1.0253	1.0203	1.0200
818	1.0168	1.0163	NA	NA	NA	NA
820	0.9929	0.9926	NA	NA	NA	NA
822	0.9899	0.9895	NA	NA	NA	NA
824	1.0200	1.0082	1.0259	1.0158	1.0226	1.0116
826	NA	NA	1.0257	1.0156	NA	NA
828	1.0202	1.0074	1.0260	1.0151	1.0228	1.0109
830	1.0252	0.9894	1.0287	0.9982	1.0271	0.9938
854	1.0253	0.9890	1.0288	0.9978	1.0272	0.9934
852	1.0359	0.9581	1.0345	0.9680	1.0360	0.9637
RG2	1.0359	1.0359	1.0345	1.0345	1.0360	1.0360
832	1.0359	1.0359	1.0345	1.0345	1.0360	1.0360
858	1.0333	1.0336	1.0321	1.0322	1.0339	1.0338
834	1.0303	1.0309	1.0293	1.0295	1.0315	1.0313
842	1.0303	1.0309	1.0292	1.0294	1.0315	1.0313
844	1.0300	1.0307	1.0289	1.0291	1.0312	1.0311
846	1.0303	1.0309	1.0289	1.0291	1.0315	1.0313
848	1.0303	1.0310	1.0290	1.0291	1.0316	1.0314
860	1.0298	1.0305	1.0289	1.0291	1.0312	1.0310
836	1.0295	1.0303	1.0285	1.0287	1.0311	1.0308
840	1.0295	1.0303	1.0285	1.0287	1.0311	1.0308
862	1.0295	1.0303	1.0285	1.0287	1.0311	1.0308
838	NA	NA	1.0283	1.0285	NA	NA
864	1.0311	1.0336	NA	NA	NA	NA
XF1	0.9997	0.9997	0.9983	0.9983	0.9998	1.0000
888	0.9994	0.9996	0.9982	0.9983	0.9998	1.0000
890	0.9134	0.9167	0.9214	0.9235	0.9221	0.9177
856	NA	NA	1.0287	0.9977	NA	NA

Voltage Angles:

TABLE VI Comparison of load angle at various buses for 34 bus system

Bus NO.	Simulink	IEEE	Simulink	IEEE	Simulink	IEEE
	Angle (Va)	Angle (Va)	Angle (Vb)	Angle (Vb)	Angle (Vc)	Angle (Vc)
800	1.0500	1.0500	1.0500	1.0500	1.0500	1.0500
802	1.0492	1.0475	1.0492	1.0484	1.0492	1.0484
806	1.0487	1.0457	1.0487	1.0474	1.0487	1.0474
808	1.0387	1.0136	1.0405	1.0296	1.0398	1.0289
810	NA	NA	1.0403	1.0294	NA	NA

812	1.0270	0.9763	1.0321	1.0100	1.0289	1.0069
814	1.0177	0.9467	1.0255	0.9945	1.0203	0.9893
RG1	1.0177	1.0177	1.0255	1.0255	1.0203	1.0203
850	1.0177	1.0176	1.0255	1.0255	1.0203	1.0203
816	1.0177	1.0172	1.0255	1.0253	1.0203	1.0200
818	1.0168	1.0163	NA	NA	NA	NA
820	0.9929	0.9926	NA	NA	NA	NA
822	0.9899	0.9895	NA	NA	NA	NA
824	1.0200	1.0082	1.0259	1.0158	1.0226	1.0116
826	NA	NA	1.0257	1.0156	NA	NA
828	1.0202	1.0074	1.0260	1.0151	1.0228	1.0109
830	1.0252	0.9894	1.0287	0.9982	1.0271	0.9938
854	1.0253	0.9890	1.0288	0.9978	1.0272	0.9934
852	1.0359	0.9581	1.0345	0.9680	1.0360	0.9637
RG2	1.0359	1.0359	1.0345	1.0345	1.0360	1.0360
832	1.0359	1.0359	1.0345	1.0345	1.0360	1.0360
858	1.0333	1.0336	1.0321	1.0322	1.0339	1.0338
834	1.0303	1.0309	1.0293	1.0295	1.0315	1.0313
842	1.0303	1.0309	1.0292	1.0294	1.0315	1.0313
844	1.0300	1.0307	1.0289	1.0291	1.0312	1.0311
846	1.0303	1.0309	1.0289	1.0291	1.0315	1.0313
848	1.0303	1.0310	1.0290	1.0291	1.0316	1.0314
860	1.0298	1.0305	1.0289	1.0291	1.0312	1.0310
836	1.0295	1.0303	1.0285	1.0287	1.0311	1.0308
840	1.0295	1.0303	1.0285	1.0287	1.0311	1.0308
862	1.0295	1.0303	1.0285	1.0287	1.0311	1.0308
838	NA	NA	1.0283	1.0285	NA	NA
864	1.0311	1.0336	NA	NA	NA	NA
XF1	0.9997	0.9997	0.9983	0.9983	0.9998	1.0000
888	0.9994	0.9996	0.9982	0.9983	0.9998	1.0000
890	0.9134	0.9167	0.9214	0.9235	0.9221	0.9177
856	NA	NA	1.0287	0.9977	NA	NA

VI. CONCLUSION

This document presents the Simulink load model for radial distribution node test feeders. This study aims to compare the load flow solutions provided by Simulink and the IEEE Radial Distribution Subcommittee. It has been done to compare the voltage magnitude and voltage angles at various buses for various phases. For load flow convergence, the Simulink model requires a very small number of iterations. The sole presumption in the Simulink model is that the voltage regulator will be replaced with a three-phase source of equal rating. We can observe from the power flow solution tables that the losses are lower than those given in the IEEE subcommittee report. Simulink models with low losses can be useful to academics working in the fields of power systems.

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The load flow solution obtained by Simulink is converged in 5 iterations for 34 node test feeders. The power flow result obtained are shown in Table VII

TABLE VII Power flow solution

Location	Active Power in KW	ReactivePower in KVAR
Total generation	1915.54	192.37
Total PQ load	1123.28	612.85
Total Z shunt load	673.10	-351.13
Total losses	119.16	-69.35