ISSN 2303-4521
Original Research
Periodicals of Engineering and Natural Sciences
Vol. 10, No. 3, June 2022, pp.311-322

Electrical distribution grid of Kirkuk City: A case study of load flow and short circuit valuation using ETAP

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ABSTRACT

The load flow study and short circuit analysis can be considered as the backbone of the electrical power network. This study based on real data collected from 12 substations, each substation contains many feeders provide the electricity network of Kirkuk city (a city in Iraq located at the north of Baghdad). The methodology of this article depended on using the Electrical Transient Analyzer Program (ETAP) software in assessing the performance of Iraqi electrical distribution network (Kirkuk city as a model) by starting modeling and simulation in order to assess the reliability through testing the load flow, and short circuit test. A complete study of load flow assessment of an actual Kirkuk city power distribution network with actual load values is presented (data have been taken from the Directorate of Electricity Distribution of Kirkuk city). The results of modeling the whole city and the detailed reports of this study can give us a comprehensive assessment with the presence of actual loads values, including total demand, PF, transmission line parameters, and the weakness points of the electrical grid.

Keywords: Load flow analysis, Short circuit analysis, ETAP software.

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1. Introduction:

The power flow method is a technique used at fundamental frequency, for calculating the steady state voltages of electric power systems [1]. The studies of power (load) flow are essential for assessing any system to understand the losses including harmonics and transmission losses [2]. In the context of power systems, load flow refers to the network's steady-state solution. Commercial power systems are frequently too complex to allow for power flow management solutions[3]. Large-scale digital computers have replaced comparable approaches with numerical solutions to perform the power flow study. Related computer programs that deal with extended calculations, such as short-circuit fault checks, stability analyses with an emphasis on transient and steady-state scenarios, and economic dispatch, are also widely used in the business sector [4].
Maintaining a high level of system security, as well as the economic operation of these systems, is one of the most important features of power systems to consider [3]. In 1956, load flow calculation studies were started using the Ward's method, which is a very basic and significant instrument in the field of power system engineering [1]. Since the discovery, many solutions for solving the load flow problem have been devised, including the Newton-Raphson and Gauss-Seidel approaches. The majority of these methods have focused on transmission systems, with Newton technique modifications such as the rapid decoupling method becoming the most prevalent over time. Distribution networks are characterized by radial topology and feeders with a high R/X ratio [3]. In the case of such networks, traditional power flow algorithms indicate convergence

issues. As a result, over time, particular power flow methods have emerged that take use of the unique properties of distribution networks, such as their radial nature and the availability of only one voltage-controlled bus. These algorithms are classed as Distribution System Load Flow (DSLF) methods because they are more efficient and simple for radially oriented networks than the traditional Gauss-Seidel (GS) and Newton-Raphson (NR) methods[5]. However, the use of FACTS technology and the creation of distributed generators have made the distribution system, and hence the DSLF procedures, substantially more complicated than prior versions, have rendered the distribution system, and hence the DSLF procedures, significantly more sophisticated than previous versions. Thus, Through an exhaustive bibliographic study, the growth of today's three phase unbalanced DSLF with numerous feeding sources, embedded FACTS devices, advanced software techniques, and so on has been documented in this work [6, 7].

The authors of [8] proposed Newton Raphson on three-phase system for power-flow due to its robust convergence. The fast decoupled method in 3-phase system was introduced by Authors in [9]. Also, Gauss-Seidel method was introduced in [10] to solve the Y Bus. In [11], the authors reported a quick estimated technique for fixing the ac power flow difficulty during phase and generator power failures. For an approximate solution, the approach is substantially more accurate than any linear calculation and considerably faster than the Newton-Raphson method. This method can be used in system planning to find design standard violations quickly, and it's especially well-suited for system control as an on-line security inspector [12]. The inaccurate Newton-Krylov approach was used to solve load flow troubles by the authors of [13]. The authors investigate the use of an iterative approach to explain linear schemes, which leads to the Newton-Krylov method, which is inexact. The blurry loads have been taking into account using Newton-Raphson (NR) load flow method with the existence of the distributed generations in the electrical network in [13, 14].

Short circuit problems in electrical systems cannot be prevented, therefore, short circuit calculation can be considered as one of the most significant computations in any system analysis. As a result, all equipment used for the electrical system should be capable of handling the highest probable fault current. Furthermore, all protective devices must be capable of detecting the smallest potential fault current in the system. Protective tool should be capable of safely clearing any fault current in the system. Protecting equipment must also clear the defect within the protection equipment's withstand time [15].

Short Circuit Analysis (SCA) is typically used to determine the system's highest and lowest fault currents. Usually, all electrical equipment's short circuit withstand capacity is determined by using the greatest available fault current. Also, the earthing order is designed based on the greatest fault current for a Line to Ground (LG) failure. On the other hand, the instantaneous over current relay's pickup setting is selected using the minimum available fault current [9].

The other application of ETAP software is the performing of short circuit analysis relies on IEC standards. SCA requires source impedance and the grid's rated voltage. Grid modelling in ETAP requires the grid's rated voltage, 1- phase short circuit apparent power, its impedance ratio X/R, and the apparent power on 3- phase short circuit (MVAsc) [16]. The demand loads connected to the buses through transformers are generally used to determine the rated apparent power. The transformer's impedance can be selected by calculating the fault current. If the fault current at the transformer's secondary has been lowered, a higher impedance value (relative to the impedance value stated in [16] can be taken.

2. Methodology

SCA can be performed in ETAP by selecting the (Run) icon for single line to ground (L-G), line to line (L-L), and double line to ground (L-L-G) faults. Among other things, ETAP software may determine initial symmetrical RMS current, steady-state root mean square (rms) current, peak current, and current-voltage angle. The ETAP output report saves the SCA results. The highest short circuit current can be calculated by selecting the study case and design state modeled for the highest available fault current. Similarly, selecting the appropriate study case and setup condition is required to calculate the minimum available short circuit current.

2.1. Requirements for short circuit current study

It is necessary to specify the terms used in defining the short circuit or the fault current characteristics in order to compute short circuit current tasks on power system equipment. The short circuit current and its tools are used to identify short circuit defects. The figure no.1 shown below, L and R represent the circuit inductance and resistance for each phase, and v(t) is the source and the spiky line represents the short circuit current on each phase.

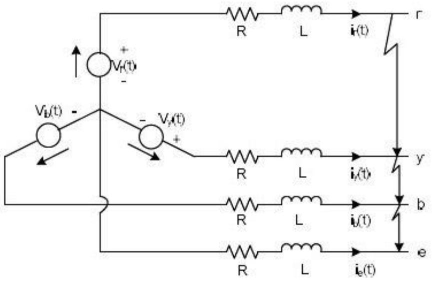

Figure 1. Basic balanced three-phase electric circuit with earth return

The electrical grid with distributed loads of Kirkuk city districts in the form of single line diagram using ETAP program is displayed in figures 2a and 2b. They are showing the two transformers (33/11) Kv which supply the power to the consumers through the feeders shown in the figures. Transformers no.1 and no.2 are providing electricity to buses no.3 and no.4 respectively. 15 feeders are used in order to distribute the power to the consumers with the electricity according to the demand loads.

ETAP simulation can be used to provide a thorough model of our system. In addition, currents, bus voltages, branch power factors, active and reactive power flows may all be calculated using ETAP simulation throughout this substation's system. An alert summary report has been created after performing load flow analysis using ETAP software, as shown in TABLE-1. This table explains the weak points of the system which urge for fast intervention. Also, it can be easily concluded from the table no.1 that the buses 3, 4 and 5 are operating at under voltage condition.

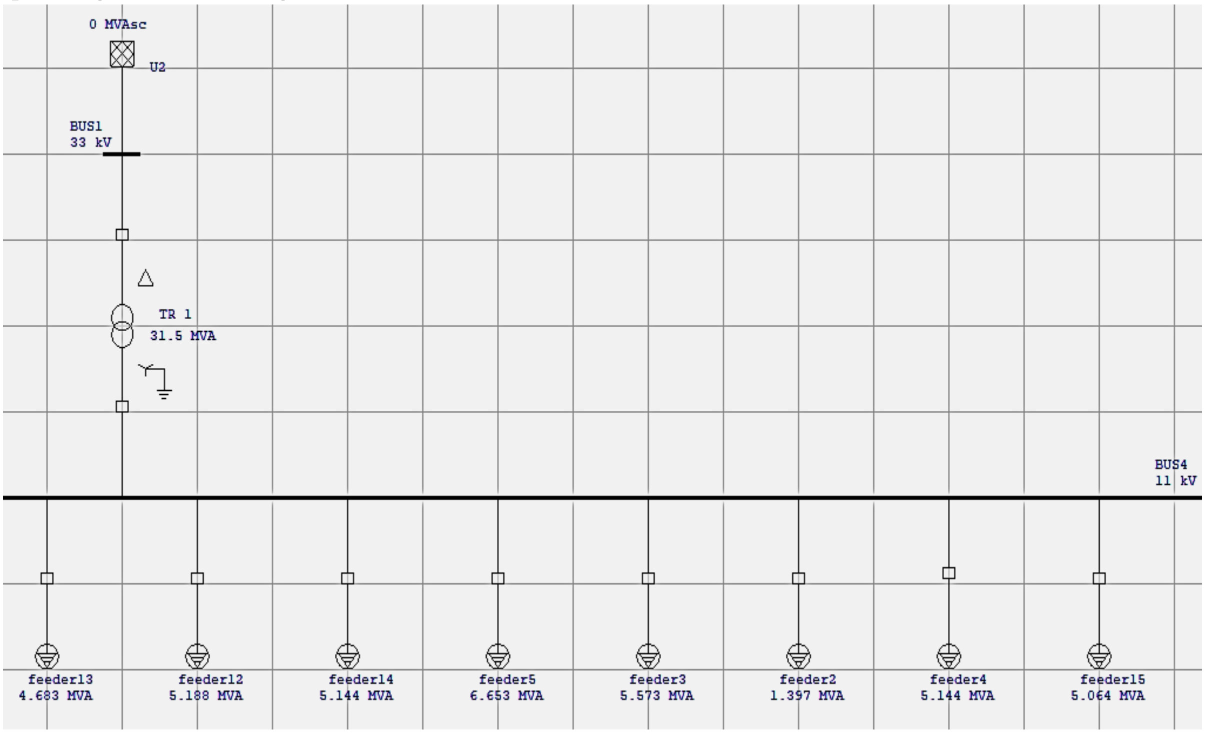

Figure2a. The left side of Qadsiya district power grid

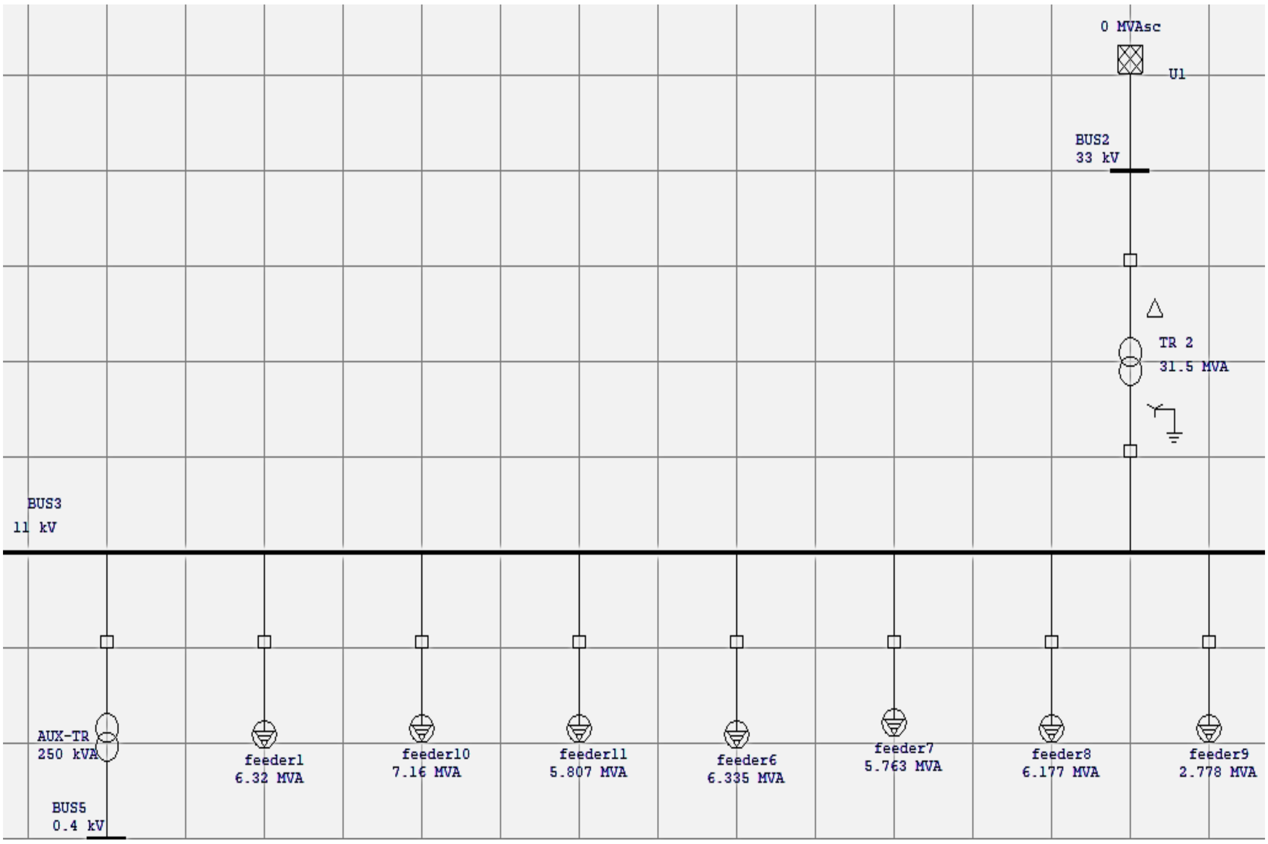

Figure 2b. The right side of Qadsiya district power grid

Table 1. Alert summary report for Qadsiya district

Device ID	Type	Condition	Rating/Limit	Operating	% Operating	Phase Type
TR 2	Transformer	Overload	31.5 MVA	41.158	130.7	3-Phase
TR 1	Transformer	Overload	31.5 MVA	41.635	132.2	3-Phase
BUS5	Bus	Under Voltage	0.4 kV	0.369	92.2	3-Phase
BUS4	Bus	Under Voltage	11 kV	10.254	93.2	3-Phase
BUS3	Bus	Under Voltage	11 kV	10.254	93.2	3-Phase

Table 2. Distribution of loads (S, P, Q, A) on all feeders in Qadsiya district

ID	Rating	Rated kV	kW	KVar	Amp (A)
feeder1	6320 kVA	11	5231	3242	346.5
feeder2	1397 kVA	11	1156	717	76.6
feeder3	5573 kVA	11	4613	2859	305.6
feeder4	5144 kVA	11	4258	2639	282
feeder5	6653 kVA	11	5507	3413	364.8
feeder6	6335 kVA	11	5244	3250	347.3
feeder7	5763 kVA	11	4771	2957	316
feeder8	6177 kVA	11	5113	3169	338.7
feeder9	2778 kVA	11	2299	1425	152.3
feeder10	7160 kVA	11	5927	3673	392.6
feeder11	5807 kVA	11	4807	2979	318.4
feeder12	5188 kVA	11	4294	2661	284.5
feeder13	4683 kVA	11	3876	2402	256.8
feeder14	5144 kVA	11	4258	2639	282
feeder15	5064 kVA	11	4192	2598	277.7
SERVICE	69.3 kVA	0.4	57.115	35.397	105.2

On the other hand, TABLE 2 shows the summary report of the real values of yearly demand loads of a specified district (Qadsiya) as a case study. This report tells us accurately the total demands in different ways such as; Active (real) power (P) in watt, Apparent power (S) in VA, reactive power (Q) in VAr, and current (I) in ampere on each feeder of the system.

TABLE-3 presents the load flow analysis of the Qadsiya substation which conducted using ETAP in which Newton-Raphson technique [5, 6] is used. Under voltage cases can be noted from figures (2a & 2b) on the 11 kV side at the buses number (2, 3 and 8). Also, at buses no. 2 & 3 the voltage level is 92.55% and at bus 8 the voltage level is 98.58%.

TABLE-3 Load flow report of Qadsiya district

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF
Bus2	11.000	92.558	-6.1	0	0	27.200	16.857	Bus6	-26.200	-16.237	1747.9	85.0
								Bus3	-1.000	-0.620	66.7	85.0
Bus3	11.000	92.558	-6.1	0	0	25.200	15.618	Bus7	-26.200	-16.237	1747.9	85.0
								Bus2	1.000	0.620	66.7	85.0
* Bus6	33.000	100.000	0.0	26.293	20.437	0	0	Bus2	26.293	20.437	582.6	79.0
* Bus7	33.000	100.000	0.0	31.961	24.120	0	0	Bus3	26.293	20.437	582.6	79.0
								Bus8	5.667	3.683	118.3	83.9
Bus8	11.000	98.580	-1.2	0	0	5.664	3.510	Bus7	-5.664	-3.510	354.8	85.0

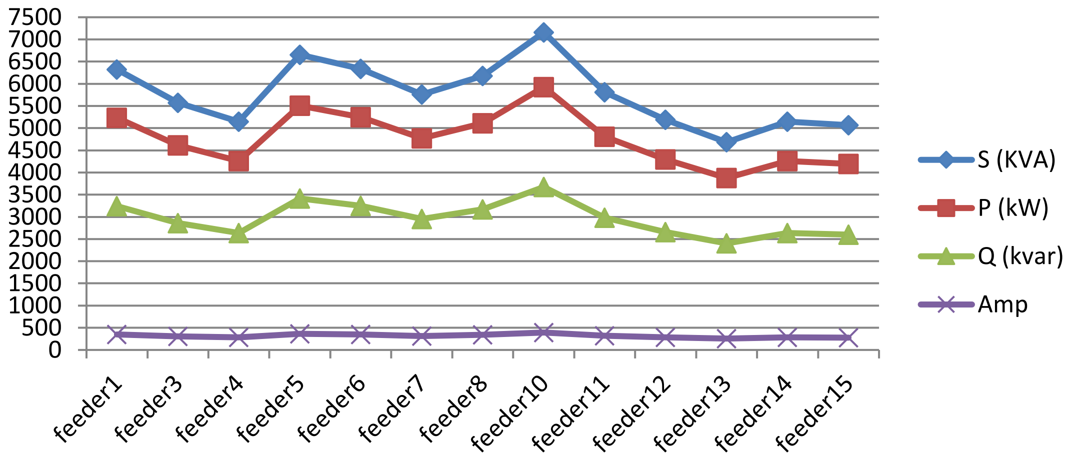

Figure 3. Distribution of loads (S, P, Q, A) on all feeders in Qadsiya district

Figure-3 illustrates the four load curves which represent the real values taken from the substations for one whole year and the average values have been taken for all available feeders of Qadsiya district. These four curves which shown above present the annual average values recorded for one year and distributed through 13 feeders. The first curve represents the apparent rated power (S), the second curve is the demand active power (P), the third curve is the reactive power (Q), and finally the fourth curve is the consumed current (A) with 13 feeders distributed in just one district (Qadsiya district has been chosen as a sample). These values have been calculated for other 12 districts in Kirkuk city.

2.2. Short circuit analysis

The specific functions or questions can ensure the monitoring of a substation at high-voltage levels and the defects of insulation cables. Therefore, the local grid requires a protection plan from various sorts of short circuit cases. Depending on the load distribution, these electrical substations can be found in a number of locations [17].

Fault at bus : **Bus2**
Nominal kV = 11.00 1.10 (User-Defined)

Line-To-Ground Fault

Contribution		% Voltage at From Bus						Current at From Bus (kA)						Sequence Current		
From Bus	To Bus	Va		Vb		Vc		Ia		Ib		Ic				
ID	ID	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	I1	I2	I0
Bus2	Total	0.00	0.0	109.81	-126.9	107.95	127.7	41.389	-87.7	0.000	0.0	0.000	0.0	13.796	13.796	13.796
Bus6	Bus2	98.58	30.6	100.00	-90.0	98.42	149.6	15.364	-88.6	2.669	-85.1	2.669	-85.1	4.234	4.234	6.898
Lump2	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.868	-85.1	0.434	94.9	0.434	94.9	0.434	0.434	0.000
Lump3	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.897	-85.1	0.449	94.9	0.449	94.9	0.449	0.449	0.000
Lump4	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.911	-85.1	0.455	94.9	0.455	94.9	0.455	0.455	0.000
Lump5	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	1.092	-85.1	0.546	94.9	0.546	94.9	0.546	0.546	0.000
Lump6	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.945	-85.1	0.473	94.9	0.473	94.9	0.473	0.473	0.000
Lump7	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.828	-85.1	0.414	94.9	0.414	94.9	0.414	0.414	0.000
Bus7	Bus3	98.58	30.6	100.00	-90.0	98.43	149.6	15.366	-88.6	2.668	-85.1	2.668	-85.1	4.235	4.235	6.898
Lump8	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.116	-85.1	0.558	94.9	0.558	94.9	0.558	0.558	0.000

Table 4. Line to ground fault when fault on bus-2

for Qadsiya district, the faults associated with the Short Circuit (SC) summary report, give a better description to understand the electrical grid. For example, this design can show the comparison of line-line to ground and line-line fault generate a short circuit current that is dependent on many factors such as the balanced voltage, the visible impedance of the fault, and the short circuit power.

Table 5. Line to ground fault when fault on bus-3 for Qadsiya

Project: ETAP Page: 3
Contract: Date: 16-07-2021
Engineer: SN:
Location: 12.6.0H Revision: Base
Filename: QADISYA~ Config.: Normal

Study Case: SC

Fault at bus : Bus3
Nominal kV = 33.00 1.10 (User-Defined)

Line-To-Ground Fault

Contribution		% Voltage at From Bus						Current at From Bus (kA)						Sequence Current (kA)		
From Bus	To Bus	Va		Vb		Vc		Ia		Ib		Ic				
ID	ID	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	I1	I2	I0
Bus3	Total	0.00	0.0	109.81	-126.9	107.95	127.7	41.389	-87.7	0.000	0.0	0.000	0.0	13.796	13.796	13.796
Bus2	Bus3	100.00	0.0	100.00	-120.0	100.00	120.00	1.028	-85.1	0.502	94.9	0.514	0.00	1.489	1.432	1.437
Bus7	Bus3	98.58	30.6	100.00	-90.0	98.43	149.6	15.366	-88.6	2.668	-85.1	2.668	-85.1	4.235	4.235	6.898
Lump8	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.116	-85.1	0.558	94.9	0.558	94.9	0.558	0.558	0.000
Lump9	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.004	-85.1	0.502	94.9	0.502	94.9	0.502	0.502	0.000
Lump10	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	0.977	-85.1	0.489	94.9	0.489	94.9	0.489	0.489	0.000
Lump11	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.028	-85.1	0.514	94.9	0.514	94.9	0.514	0.514	0.000
Lump15	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.008	-85.1	0.504	94.9	0.504	94.9	0.504	0.504	0.000
Bus6	Bus2	98.58	30.6	100.00	-90.0	98.42	149.6	15.364	-88.6	2.669	-85.1	2.669	-85.1	4.234	4.234	6.898
Lump2	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.868	-85.1	0.434	94.9	0.434	94.9	0.434	0.434	0.000
Lump3	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.897	-85.1	0.449	94.9	0.449	94.9	0.449	0.449	0.000
Lump4	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.911	-85.1	0.455	94.9	0.455	94.9	0.455	0.455	0.000
Lump5	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	1.092	-85.1	0.546	94.9	0.546	94.9	0.546	0.546	0.000
Lump6	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.945	-85.1	0.473	94.9	0.473	94.9	0.473	0.473	0.000
Lump9	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.004	-85.1	0.502	94.9	0.502	94.9	0.502	0.502	0.000
Lump7	Bus2	100.00	0.0	100.00	-120.0	100.00	120.0	0.828	-85.1	0.414	94.9	0.414	94.9	0.414	0.414	0.000
Lump10	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	0.977	-85.1	0.489	94.9	0.489	94.9	0.489	0.489	0.000
Bus8	Bus7	98.23	0.1	99.64	-119.5	99.48	119.6	0.010	-89.9	0.000	0.000	0.010	90.1	0.006	0.006	0.000
Lump15	Bus3	100.00	0.0	100.00	-120.0	100.00	120.0	1.008	-85.1	0.504	94.9	0.504	94.9	0.504	0.504	0.000
U4	Bus7	100.00	30.0	100.00	-90.0	100.00	150.0	2.435	-89.4	0.000	90.6	2.435	90.6	1.406	1.406	0.000
U3	Bus6	100.00	30.0	100.00	-90.0	100.00	150.0	2.444	-89.4	0.000	90.6	2.444	90.6	1.411	1.411	0.000
U3	Bus6	100.00	30.0	100.00	-90.0	100.00	150.0	2.444	-89.4	0.000	90.6	2.444	90.6	1.411	1.411	0.000
Bus8	Bus7	98.23	0.1	99.64	-119.5	99.48	119.6	0.010	-89.9	0.000	0.000	0.010	90.1	0.006	0.006	0.000
U4	Bus7	100.00	30.0	100.00	-90.0	100.00	150.0	2.435	-89.4	0.000	90.6	2.435	90.6	1.406	1.406	1.406

Table 6. Line to ground fault when fault on bus-7 for Qadsiya

Project:	ETAP	Page: 4
Location:	12.6.0H	Date: 16-07-2021
Contract:		SN:
Engineer:		Revision: Base
Filename: QADISYA~	Study Case: SC	Config.: Normal

Fault at bus : Bus7

Nominal kV = 33.00 1.10 (User-Defined)

Line-To-Ground Fault

Contribution		% Voltage at From Bus						Current at From Bus (kA)						Sequence Current (kA)		
From Bus	To Bus	Va		Vb		Vc		Ia		Ib		Ic				
ID	ID	Mag	Ang	Mag	Ang	Mag	Ang	Mag	Ang	Mag	Ang	Mag	Ang	I1	I2	I0
Bus7	Total	0.00	0.0	100.45	-120.5	100.54	120.5	142.716	-84.4	0.000	0.0	0.000	0.0	47.572	47.572	47.572
Bus3	Bus7	84.59	-35.8	85.22	-143.6	100.00	90.0	2.365	-87.9	1.182	92.1	1.182	92.1	1.182	1.182	0.000
Bus8	Bus7	61.23	-54.1	61.91	-125.5	100.00	90.0	0.392	-84.8	0.196	95.2	0.196	95.2	0.196	0.196	0.000
U4	Bus7	100.00	0.0	100.00	-120.0	100.00	120.0	139.964	-84.3	1.378	-87.4	1.378	-87.4	46.196	46.196	47.572
Lump8	Bus3	100.00	-30.0	100.00	-150.0	100.00	90.0	0.358	-86.0	0.358	94.0	0.000	94.0	0.207	0.207	0.000
Lump9	Bus3	100.00	-30.0	100.00	-150.0	100.00	90.0	0.322	-86.0	0.322	94.0	0.000	94.0	0.186	0.186	0.000
Lump10	Bus3	100.00	-30.0	100.00	-150.0	100.00	90.0	0.314	-86.0	0.314	94.0	0.000	94.0	0.181	0.181	0.000
Lump11	Bus3	100.00	-30.0	100.00	-150.0	100.00	90.0	0.330	-86.0	0.330	94.0	0.000	94.0	0.191	0.191	0.000
Lump15	Bus3	100.00	-30.0	100.00	-150.0	100.00	90.0	0.324	-86.0	0.324	94.0	0.000	94.0	0.187	0.187	0.000
Bus6	Bus2	99.26	0.0	99.85	-119.8	99.78	119.8	2.720	-90.3	2.720	89.7	0.000	89.7	1.570	1.570	0.000
Lump2	Bus2	100.00	-30.0	100.00	-150.0	100.00	90.0	0.279	-86.0	0.279	94.0	0.000	94.0	0.161	0.161	0.000
Lump3	Bus2	100.00	-30.0	100.00	-150.0	100.00	90.0	0.288	-86.0	0.288	94.0	0.000	94.0	0.166	0.166	0.000
Lump4	Bus2	100.00	-30.0	100.00	-150.0	100.00	90.0	0.293	-86.0	0.293	94.0	0.000	94.0	0.169	0.169	0.000
Lump5	Bus2	100.00	-30.0	100.00	-150.0	100.00	90.0	0.351	-86.0	0.351	94.0	0.000	94.0	0.203	0.203	0.000
Lump6	Bus2	100.00	-30.0	100.00	-150.0	100.00	90.0	0.304	-86.0	0.304	94.0	0.000	94.0	0.175	0.175	0.000
Lump7	Bus2	100.00	-30.0	100.00	-150.0	100.00	90.0	0.266	-86.0	0.266	94.0	0.000	94.0	0.153	0.153	0.000
Lump17	Bus8	100.00	-30.0	100.00	-150.0	100.00	90.0	1.020	-84.8	1.020	95.2	0.000	95.2	0.589	0.589	0.000

Figure 4, presents the percentage rated voltage and the maximum current on each lump (load) when fault occurs on bus no.2 for Qadsiya district. Also, it shows the positive sequence impedance and the zero sequence impedance parameters of resistor and inductance (R & X). In addition, this table presents the maximum primary current, highest steady state current, and breaking current in all three well-known types of short circuit cases; Single Line to Ground (SLG), Line to Line Ground (LLG), and three lines to ground (3LG) connections[18].

On the same way, figure 8 present the same information as figure 4 but when the fault happens on bus no. 8 in Qadsiya district. The changes in the values of parameters are normal due to altering of the faulted bus.

2.3. Simulation and modeling of Kirkuk city in one big system

This research covered the concept of modeling a whole city (Kirkuk as an example city) in two stages; first step conducted an individual grid for each substation in the city, each substation covers specific districts in the city. The research team has collected the data of 12 substations, however due to lack of writing space, the Qadsiya substation has been chosen randomly as a sample substation for evaluation.

On the second stage, all the 12 substations have been combined in one big system. The tables (7 & 8) below show the rated voltage, the percentage magnitude of voltage, and the phase shift angle. In addition, it shows the generated active power, reactive power, the distributed power (MW, MVAR, and PF) for each bus bar.

Table 7. Load flow report for main substations in Kirkuk city

Voltage	% Mag	Angle			% Mag.	Ang.	**Bus**	Load flow		Generation	
								MW	Mvar	MW	Mvar
11.000	95.048	-4.1	0	0	15.135	9.380	Bus3	-18.344	-11.368	1191.7	85.0
							Bus2	3.208	1.988	208.4	85.0
11.000	95.048	-4.1	0	0	21.552	13.357	Bus4	-18.344	-11.368	1191.7	85.0
33.000	100.000	0.0	18.550	13.422	0	0	Bus1	18.387	13.321	397.2	81.0
33.000	100.000	0.0	18.585	13.443	0	0	Bus2	18.387	13.321	397.2	81.0
							Bus6	0.198	0.123	4.1	85.0
11.000	99.952	0.0	0	0	0.198	0.123	Bus4	-0.198	-0.123	12.2	85.0
33.000	100.000	0.0	35.073	17.380	0	0	Bus13	30.570	14.482	591.8	90.4
							Bus15	4.504	2.898	93.7	84.1
33.000	100.000	0.0	9.755	11.707	0	0	Bus14	5.774	9.156	189.4	53.3
							Bus16	3.981	2.551	82.7	84.2
11.000	96.507	-1.3	0	0	16.916	10.484	Bus11	-29.800	-13.328	1775.4	91.3
							Bus14	12.884	2.844	717.6	97.6
11.000	96.507	-1.3	0	0	18.648	11.557	Bus12	-5.764	-8.712	568.1	55.2
11.000	98.879	-1.0	0	0	4.501	2.790	Bus11	-4.501	-2.790	281.1	85.0
11.000	99.012	-0.9	0	0	3.980	2.466	Bus12	-3.980	-2.466	248.2	85.0
11.000	93.239	-5.5	0	0	25.266	15.658	Bus26	-24.133	-14.956	1598.2	85.0
							Bus23	-1.133	-0.702	75.0	85.0
11.000	81.055	-14.1	0	0	53.049	32.877	Bus26	-53.049	-32.877	4041.3	85.0
11.000	93.239	-5.5	0	0	23.000	14.254	Bus25	-24.133	-14.956	1598.2	85.0
11.000	99.429	-0.1	0	0	4.376	2.712	Bus25	-4.376	-2.712	271.7	85.0
33.000	100.000	0.0	28.604	21.206	0	0	Bus23	24.211	18.467	532.7	79.5
							Bus24	4.394	2.739	90.6	84.9
33.000	100.000	0.0	77.759	73.796	0	0	Bus21	24.211	18.467	532.7	79.5
							Bus22	53.548	55.329	1347.1	69.5

Table 8. Load flow report for whole Kirkuk city

BUS	*kV*	*% Mag.*	*Ang.*	*MW*	*Mvar*	*MW*	*Mvar*	*Bus*	*MW*	*Mvar*	*Amp*	*%PF*
** Bus49*	*33.000*	*100.000*	*0.0*	*20.925*	*14.897*	*0*	*0*	*Bus47*	*4.950*	*3.068*	*321.5*	*85.0*
								Bus48	*18.231*	*13.190*	*393.7*	*81.0*
								Bus106	*2.693*	*1.707*	*55.8*	*84.5*
** Bus54*	*33.000*	*100.000*	*0.0*	*26.243*	*20.388*	*0*	*0*	*Bus55*	*26.243*	*20.388*	*581.4*	*79.0*
Bus55	*11.000*	*92.575*	*-6.1*	*0*	*0*	*25.499*	*15.803*	*Bus54*	*-26.150*	*16.206*	*1744.2*	*85.0*
Bus56	*11.000*	*92.575*	*-6.1*	*0*	*0*	*26.800*	*16.609*	*Bus56*	*0.650*	*0.403*	*43.4*	*85.0*
** Bus57*	*33.000*	*100.000*	*0.0*	*26.829*	*20.754*	*0*	*0*	*Bus57*	*-26.150*	*16.206*	*1744.2*	*85.0*
								Bus55	*-0.650*	*-0.403*	*43.4*	*85.0*
								Bus107	*0.587*	*0.365*	*12.1*	*84.9*
								Bus56	*26.243*	*20.388*	*581.4*	*79.0*
Bus66	*11.000*	*99.092*	*-0.8*	*0*	*0*	*3.661*	*2.269*	*Bus68*	*-3.661*	*-2.269*	*228.2*	*85.0*
** Bus68*	*33.000*	*100.000*	*0.0*	*22.531*	*16.067*	*0*	*0*	*Bus66*	*3.663*	*2.341*	*76.1*	*84.3*
** Bus69*	*33.000*	*100.00*	*0.0*	*24.147*	*17.146*	*0*	*0*	*Bus71*	*18.868*	*13.727*	*408.2*	*80.9*
Bus70	*11.000*	*94.904*	*-4.2*	*0*	*0*	*14.127*	*8.755*	*Bus70*	*18.868*	*13.727*	*408.2*	*80.9*

Bus71	*11.000*	*94.904*	*-4.2*	*0*	*0*	*23.517*	*14.575*	*Bus73*	*5.279*	*3.420*	*110.0*	*83.9*
								Bus69	*-18.822*	*11.665*	*1224.7*	*85.0*
								Bus71	*4.695*	*2.910*	*305.5*	*85.0*
								Bus68	*-18.822*	*11.665*	*1224.7*	*85.0*
								Bus70	*-4.695*	*-2.910*	*305.5*	*85.0*
Bus82	*11.000*	*98.811*	*-1.0*	*0*	*0*	*4.768*	*2.955*	*Bus69*	*-5.276*	*-3.270*	*330.1*	*85.0*
** Bus84*	*33.000*	*100.000*	*0.0*	*18.314*	*12.486*	*0*	*0*	*Bus84*	*-4.768*	*-2.955*	*297.9*	*85.0*
								Bus82	*4.770*	*3.077*	*99.3*	*84.0*
** Bus85*	*33.000*	*100.000*	*0.0*	*13.543*	*9.409*	*0*	*0*	*Bus87*	*13.543*	*9.409*	*288.5*	*82.1*
Bus86	*11.000*	*96.455*	*-3.0*	*0*	*0*	*14.404*	*8.927*	*Bus86*	*13.543*	*9.409*	*288.5*	*82.1*
								Bus85	*-13.520*	*-8.379*	*865.5*	*85.0*
Bus87	*11.000*	*96.455*	*-3.0*	*0*	*0*	*12.636*	*7.831*	*Bus87*	*-0.884*	*-0.548*	*56.6*	*85.0*
								Bus84	*-13.520*	*-8.379*	*865.5*	*85.0*
Bus90	*11.000*	*98.522*	*-1.3*	*0*	*0*	*5.889*	*3.650*	*Bus86*	*0.884*	*0.548*	*56.6*	*85.0*
** Bus92*	*33.000*	*100.000*	*0.0*	*30.617*	*22.783*	*0*	*0*	*Bus92*	*-5.889*	*-3.650*	*369.1*	*85.0*
								Bus90	*5.893*	*3.837*	*123.0*	*83.8*
** Bus93*	*33.000*	*100.000*	*0.0*	*24.724*	*18.946*	*0*	*0*	*Bus95*	*24.724*	*18.946*	*545.0*	*79.4*
Bus94	*11.000*	*93.073*	*-5.7*	*0*	*0*	*29.778*	*18.455*	*Bus94*	*24.724*	*18.946*	*545.0*	*79.4*
								Bus93	*-24.642*	*15.272*	*1634.9*	*85.0*
Bus95	*11.000*	*93.073*	*-5.7*	*0*	*0*	*19.506*	*12.089*	*Bus95*	*-5.136*	*-3.183*	*340.7*	*85.0*
								Bus92	*-24.642*	*15.272*	*1634.9*	*85.0*
** Bus100*	*33.000*	*100.000*	*0.0*	*17.736*	*12.777*	*0*	*0*	*Bus94*	*5.136*	*3.183*	*340.7*	*85.0*
** Bus101*	*33.000*	*100.000*	*0.0*	*21.692*	*15.310*	*0*	*0*	*Bus103*	*17.736*	*12.777*	*382.4*	*81.1*
								Bus102	*17.736*	*12.777*	*382.4*	*81.1*
								Bus124	*3.956*	*2.534*	*82.2*	*84.2*

Table (8) describes the load flow report of 128 buses which represent the electrical grid and the distributed loads of whole city of Kirkuk in one big diagram. This report illustrates the points of strength and weakness of the grid by showing the values of voltage (amplitude and angle), demand power (MW), reactive power (MVar) and power factor of each bus. This study can give a general vision of a network with an annual average load demand taken from recorded real data. Also, these reports and tables can describe the reliability and stability of the whole grid if necessary, information added to the report.

3. Simulation results

The short circuit calculation using ETAP produced the tables (9,10, 11, 12., These tables are Based on total bus fault current**.** The SCA tests have been done on different selected 3-phase to ground buses, the fault applied on bus no.1, no.2, no.3, no.4 in tables 9, 10, 11, 12 respectively.

Table 9. Short-circuit report when 3-phase fault applied on bus-1

From Bus ID	**To Bus ID**	**% V From Bus**	**kA Real**	**kA Imaginary**	**X/R Ratio**	**kA Magnitude**
Bus1	Total	0.00	0.959	-20.691	21.6	20.713
Bus3	Bus1	96.41	0.378	-15.112	40.0	15.117
Lump1	Bus1	100.00	0.249	-2.488	10.0	2.501
Lump2	Bus1	100.00	0.037	-0.246	6.7	0.249
Lump3	Bus1	100.00	0.262	-2.618	10.0	2.631
Lump4	Bus1	100.00	0.034	-0.226	6.7	0.229
U1	Bus3	100.00	0.126	-5.037	40.0	5.039

Table 10. Short-circuit report when 3-phase fault applied on bus-2

From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus2	Total	0.00	1.069	-21.998	20.6	22.024
Bus4	Bus2	96.41	0.378	-15.112	40.0	15.117
Lump5	Bus2	100.00	0.159	-1.594	10.0	1.602
Lump6	Bus2	100.00	0.296	-2.960	10.0	2.974
Lump7	Bus2	100.00	0.228	-2.277	10.0	2.288
Lump8	Bus2	100.00	0.008	-0.057	6.7	0.057
U2	Bus4	100.00	0.126	-5.037	40.0	5.039

Table 12. Short-circuit report when 3-phase fault applied on bus-4

From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus4	Total	0.00	14.049	-140.866	10.0	141.565
Bus2	Bus4	30.64	0.122	-1.597	13.1	1.602
U2	Bus4	100.00	13.927	-139.269	10.0	139.964
Lump5	Bus2	100.00	0.084	-1.109	13.2	1.112
Lump6	Bus2	100.00	0.156	-2.059	13.2	2.065
Lump7	Bus2	100.00	0.120	-1.584	13.2	1.588
Lump8	Bus2	100.00	0.005	-0.039	13.2	0.212

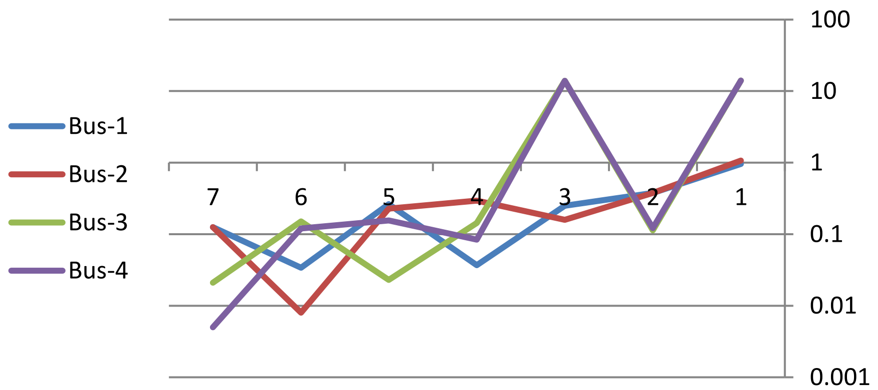

Figure 4. Distribution of fault currents in four different buses on Qadsiya substation

Tables (9, 10, 11, and 12) can be collected in one figure. This chart presents 4 curves represent the real values of ampere (in KA) on many buses and lumps when fault occurred on bus number 1, 2, 3, and 4 respectively.

4. Conclusion

Both planning future power system growth and determining how to operate current systems effectively require load-flow and short circuit studies. In this work, an analysis of a Kirkuk city power grid is carried out using ETAP software with the aim of overcoming the problems of under-voltage, line losses, and voltage dips. Also, a number of operational evaluations, for example, the faults at bus bars, feeders, and loads, can be investigated. In example, this can be used to find the best size and placement of capacitors to overcome an under-voltage problem. They're also effective for determining system voltages when loads are rapidly applied or lost.

Load flow researches examine whether system voltages stay within prescribed limits under a variety of possible scenarios or not. Also, it examines the condition of equipment in example conductors or transformers whether they are overloaded or not. Load flow study is frequently employed for determining the requirement of further generation, additional reactive energy or called VAR support, in other words, the insertion of capacitors (X_C) or reactors (X_L) to keep system voltages within prescribed edges.

Short circuit researches are the most crucial analyses in any electrical grid because they are used conventional devices so that they can manage faults and short circuit currents. Such tests also may deliver data of the short circuit problem such as the potential damage that it can cause. These researches also aid in the proper design of the protection system. Short circuit studies are also required for relay coordination and arc flash studies.

Declaration of competing interest

The authors declare that they have no any known financial or nonfinancial competing interest.

Funding information

No funding was received from any financial organization to conduct this research.

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