Power System Fault Analysis in MATLAB

Gregory Jeffrey

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Project Summary

The purpose of this project is to analyze different types of faults on a power system given its parameters using MATLAB. For this specific case, a 14-bus system was used. The MATLAB script uses the 14-bus system's parameter data to find the fault current and all post-fault bus voltages given the type of fault and its location.

Analysis Methods

The first steps taken in the script are to collect the system parameters and the fault data using the 'xlsread' function. It is also given the type of transformer given between bus 5 and 6. The parameter data is given for the positive, negative, and zero sequence networks. The positive and negative sequence networks are identical, and the same data is used. In order to create and impedance matrix for the system, the admittance matrix $\mathbf{Y_{bus}}$ must first be created (more accurately, one admittance matrix for each of the 3 sequence networks).

The admittance matrices are created using a function 'get_Ybus', which reads the resistance and reactance data and adds it appropriately to the corresponding entries in the (in this case) 14x14 matrix. The pi-model is used for transmission lines.

For diagonal entries in $\mathbf{Y_{bus}}$, all series resistances (R), reactances (X) and shunt admittances (B) are added. For off-diagonal entries, the negative of the series admittance is the entry's value. Y_{bus} is calculated as shown below for every iteration of the loop.

$$Y_{bus}(i,i) = Y_{bus}(i,i) + \frac{1}{R_{ik}} + \frac{1}{jX_{ik}} + \frac{1}{2}jB_{ik}$$

$$Y_{bus}(i,k) = -\frac{1}{jX_{ik}} - \frac{1}{R_{ik}})$$

The generator reactances are added in a similar fashion once the initial Y_{bus} is created. The $\mathbf{Z_{bus}}$ matrix is the inverse of the $\mathbf{Y_{bus}}$ matrix for each sequence. Once $\mathbf{Z_{bus}}$ is created, the Thevenin impedance at the faulted bus can be found as the diagonal entry at that bus and can be used as the sequence networks for fault calculation.

Depending on the type of fault, the sequence networks are arranged differently in order to solve for the fault current. Refer to the MATLAB script's '*switch'* statement for the calculations used in solving for the fault current in each sequence network. The three-phase fault currents can be calculated using the sequence transformation matrix as shown below, where $\alpha = 1e^{j120}$.

$$\begin{bmatrix} {I_f}^A \\ {I_f}^B \\ {I_f}^C \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} * \begin{bmatrix} {I_f}^0 \\ {I_f}^+ \\ {I_f}^- \end{bmatrix}$$

In order to find the post-fault bus voltages, the assumption is made that all pre-fault bus voltages are nominal and positive-sequence only (i.e. $1e^{j0}$). The bus voltages are therefore calculated as shown below, where V_{bus} is a 14-entry column vector. Note that the calculation is the same for negative and zero sequences; however, the initial V_{bus} is all zeros.

$$V_{bus}{}^{+} = 1 - Z_{bus}{}^{+} * \begin{bmatrix} 0 \\ \vdots \\ I_f{}^{+}(faulted\ bus) \\ \vdots \\ 0 \end{bmatrix}$$

Finally, the 3-phase V_{bus} matrix is found using the sequence transformation matrix to give the final post-fault bus voltages. The output tables show these voltages as magnitude and phase components.

Test Cases: Output Tables

Fault Current	A		B		C	
	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
	1.733	-77.54	0	0	0	0
Bus Voltages	**A**		**B**		**C**	
Bus	**Magnitude**	**Phase**	**Magnitude**	**Phase**	**Magnitude**	**Phase**
1	0.975	-0.34	0.997	-119.88	1	119.81
2	0.971	-0.45	0.997	-119.86	0.999	119.79
3	0.988	-0.2	0.999	-119.95	1	119.93
4	0.857	-0.17	1.032	-122.94	1.032	122.95
5	0.827	0.2	1.038	-123.65	1.041	123.54
6	0.306	-13.64	1.244	-133.19	1.186	135.92
7	0.838	-1.7	1.049	-123.21	1.03	123.91
8	0.989	-0.07	1	-119.98	1	120
9	0.611	-5.7	1.134	-127.68	1.085	129.69
10	0.558	-6.72	1.153	-128.68	1.101	130.9
11	0.435	-9.4	1.198	-130.94	1.14	133.48
12	0.154	-24.12	1.301	-135.82	1.246	138.52
13	0	-26.57	1.337	-138.72	1.316	139.78
14	0.345	-6.08	1.217	-132.92	1.181	134.61

Case 1 Phase A to Ground fault at bus 13 with zero fault impedance.

Fault Current	A		B		C	
	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
	1.053	-75.62	0	0	0	0
Bus Voltages	**A**		**B**		**C**	
Bus	**Magnitude**	**Phase**	**Magnitude**	**Phase**	**Magnitude**	**Phase**
1	0.986	-0.22	0.997	-119.87	0.999	119.81
2	0.984	-0.29	0.997	-119.88	0.999	119.82
3	0.993	-0.14	0.999	-119.98	1	119.96
4	0.911	-0.2	1.02	-121.89	1.02	121.9
5	0.921	-0.13	1.011	-120.96	1.009	121.01
6	0.147	-11.86	1.437	-142.71	1.431	142.99
7	0.861	-1.73	1.059	-123.59	1.032	124.58
8	0.992	-0.07	1.001	-120.05	1	120.08
9	0.6	-5.53	1.194	-130.97	1.141	133.31
10	0.521	-6.23	1.235	-133.27	1.188	135.45
11	0.338	-7.98	1.331	-138.17	1.302	139.57
12	0.075	-22.4	1.462	-143.35	1.454	143.76
13	0	-171.47	1.479	-144.17	1.479	144.15
14	0.338	-5.89	1.311	-137.38	1.282	138.79

Case 2: Phase A to Ground fault at bus 13 with zero fault impedance, with transformer between buses 5-6 changed to ungrounded Y-Y configuration.

Fault Current	A		B		C	
	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
	0.904	-14.51	0.904	-134.51	0.904	105.49
Bus Voltages	**A**		**B**		**C**	
Bus	**Magnitude**	**Phase**	**Magnitude**	**Phase**	**Magnitude**	**Phase**
1	0.997	-0.85	0.997	-120.85	0.997	119.15
2	0.997	-0.98	0.997	-120.98	0.997	119.02
3	0.999	-0.4	0.999	-120.4	0.999	119.6
4	0.982	-2.26	0.982	-122.26	0.982	117.74
5	0.977	-2.64	0.977	-122.64	0.977	117.36
6	0.947	-10.38	0.947	-130.38	0.947	109.62
7	0.986	-2.56	0.986	-122.56	0.986	117.44
8	0.998	-0.31	0.998	-120.31	0.998	119.69
9	0.972	-5.88	0.972	-125.88	0.972	114.12
10	0.968	-6.66	0.968	-126.66	0.968	113.34
11	0.958	-8.46	0.958	-128.46	0.958	111.54
12	0.932	-12.6	0.932	-132.6	0.932	107.4
13	0.904	-14.51	0.904	-134.51	0.904	105.49
14	0.94	-9.5	0.94	-129.5	0.94	110.5

Case 3: Three-phase to Ground fault at bus 13 with 1-ohm fault impedance.

Case 4: Three-phase to Ground fault at bus 13 with 1-ohm fault impedance, with transformer between buses 5-6 changed to ungrounded Y-Y configuration. ***Result is identical to case 3.***

Fault Current	A		B		C	
	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
	0	0	3.059	-176.52	3.108	24.98
Bus Voltages	**A**		**B**		**C**	
Bus	**Magnitude**	**Phase**	**Magnitude**	**Phase**	**Magnitude**	**Phase**
1	0.998	-0.05	0.96	-121.84	0.948	120.33
2	0.998	-0.05	0.955	-122.21	0.94	120.28
3	0.999	-0.02	0.982	-120.9	0.976	120.06
4	1.041	-0.02	0.846	-121.39	0.837	120.35
5	1.05	-0.1	0.815	-121.11	0.807	120.85
6	1.234	1.16	0.313	-135.36	0.298	104.69
7	1.05	0.39	0.833	-122.64	0.824	118.49
8	1	0.01	0.982	-120.52	0.981	120.26
9	1.129	0.98	0.615	-126.85	0.6	113.83
10	1.147	1.05	0.562	-127.93	0.547	112.66
11	1.19	1.14	0.441	-130.79	0.425	109.58
12	1.288	1.07	0.162	-145.01	0.153	92.84
13	1.336	0.3	0	102.55	0	82.14
14	1.219	0.69	0.347	-127.23	0.339	113.39

Case 4: Phase B to C to Ground fault at bus 13 with zero fault impedance.

Fault Current	A		B		C	
	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
	0	0	3.059	-176.52	3.108	24.98
Bus Voltages	**A**		**B**		**C**	
Bus	**Magnitude**	**Phase**	**Magnitude**	**Phase**	**Magnitude**	**Phase**
1	0.998	-0.03	0.963	-122.03	0.95	120.57
2	0.998	-0.04	0.958	-122.41	0.942	120.54
3	1	-0.01	0.983	-120.97	0.976	120.16
4	1.023	0	0.862	-123.14	0.854	122.09
5	1.012	0.03	0.841	-124.33	0.839	123.85
6	1.378	0.11	0.278	-118.55	0.265	86.8
7	1.051	0.52	0.839	-123.41	0.831	119.21
8	1.001	0.02	0.982	-120.56	0.981	120.3
9	1.167	1.03	0.611	-126.25	0.596	113.22
10	1.204	0.92	0.552	-125.85	0.535	110.65
11	1.289	0.56	0.418	-123.82	0.397	102.65
12	1.396	0.16	0.145	-128.85	0.138	75.45
13	1.411	-0.01	0	-164.68	0	108.56
14	1.273	0.57	0.345	-126.63	0.336	112.78

Case 5: Phase B to C to Ground fault at bus 13 with zero fault impedance, with transformer between buses 5-6 changed to ungrounded Y-Y configuration.

Fault Current	A		B		C	
	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
	0	0	3.029	-165.68	3.029	14.32
Bus Voltages	**A**		**B**		**C**	
Bus	**Magnitude**	**Phase**	**Magnitude**	**Phase**	**Magnitude**	**Phase**
1	1	0	0.965	-122.17	0.951	120.76
2	1	0	0.961	-122.57	0.943	120.78
3	1	0	0.984	-121.04	0.977	120.27
4	1	0	0.884	-125.15	0.874	124.21
5	1	0	0.859	-125.91	0.855	125.51
6	1	0	0.627	-156.11	0.496	149.2
7	1	0	0.887	-126.54	0.855	123.5
8	1	0	0.984	-120.68	0.982	120.45
9	1	0	0.767	-137.27	0.679	130.02
10	1	0	0.739	-140.12	0.642	132.37
11	1	0	0.68	-147.34	0.563	139.32
12	1	0	0.576	-167.66	0.454	164.28
13	1	0	0.5	180	0.5	180
14	1	0	0.613	-151.37	0.548	147.58

Case 6: Phase B to C ungrounded fault at bus 13 with zero fault impedance.

Case 8: Phase B to C ungrounded fault at bus 13 with zero fault impedance, with transformer between buses 5-6 changed to ungrounded Y-Y configuration.

Result is identical to case 7.