**EE 455**

**CHW1**

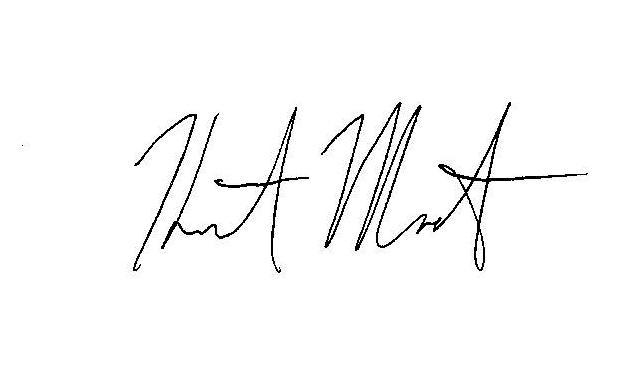
**2/13/2013**

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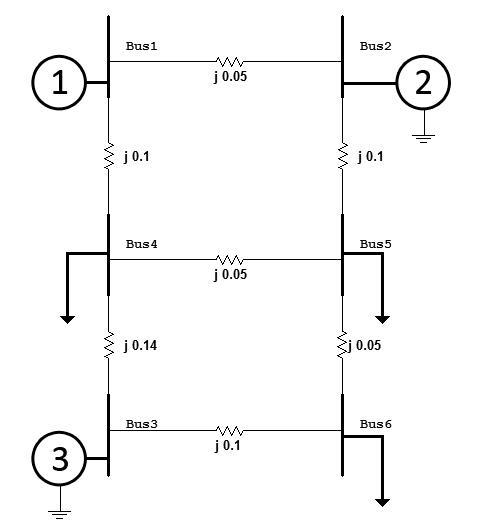


**ABSTRACT**

For the purpose of analyzing currents and voltages present in a large and complex power system under various fault conditions and at various bus locations, our team wrote a Matlab (The MathWorks, Inc.) program to perform the calculations.

**INTRODUCTION**

Given a network topology, one can use the matrix method of fault analysis to calculate network operating parameters under fault conditions for various faults at various buses. The network topology given for this project is shown in Figure 1:



**Figure 1: Network topology as presented by the problem specifications.**

Additionally, the real line resistances of all lines were zero ohms and line charging for all lines were specified as zero. Also, generator powers, load powers, generator sequence reactances and pre-fault voltages were specified as shown in Table 1 (in p.u. at a 100MVA base):



**Table 1: Specified network parameters.**

Our analysis considered 3 phase (bolted), single line to ground (bolted), double line to ground (bolted) and line to line (bolted) faults, at all buses. We also considered the impedance Zf = 0.1 p.u for the double line to ground and three phase faults. In addition, we considered the total fault impedance of 0.1 p.u. for the line to line and single line to ground faults.

**METHODOLOGY**

We came at the approach of a generic 3 phase fault impedance. We used variables for the impedances in each of the phases (Za, Zb, Zc) and the ground impedance (Zg). This way we could just set values that were really large to simulate infinite impedances (open circuits) and really small values to simulate zero impedances (short circuits). We could then find Zf and invert it to get our Yf which then led us to our generic Ysf to be used in all the cases.

To justify whether our impedances were small enough and large enough, we took couple of magnitudes smaller or larger to see if there were any changes in the output. The differences in results were very minor, about a difference of 1/10000. This is a small enough difference to prove that it didn’t affect our output significantly.

Our output data is all shown in magnitudes of phase currents (|Ia|, |Ib|, |Ic|). To calculate the magnitude between the transmission lines, we simply took the difference in phase voltages between the busses and multiplied by the admittance to get the phase currents between each bus.

To get the currents from the generators, we simply applied KCL at the bus that the generator was hooked up to. Using our previous data, we could add the currents that were going in and out of the bus to get the generator current. If the fault occurred on a bus with a generator, the fault phase current was added to the faulted bus.

**ANALYSIS**

Upon analyzing our results we found that they may be approximate to what we need. Corresponding to the fault type, we can tell whether our results were correct. Such as in a 3 phase fault would result in a larger magnitude of fault current than any of the other faults. Also we can see that if a fault occurs on a bus with a generator, the current out of the generator increases. Using this type of analysis we can assume our values are mostly correct.

**CONCLUSION**

Using our results, we can simulate any type of fault at any bus in this system. This is beneficial for us because if we wanted to size breakers or design with safety measures in mind. Our data also helps provide what settings to set the breakers’ relays at so that we can avoid inadvertent tripping to be able to provide power even during heavy load. Our data helps to avoid many different possible fault situations and to design for the worst case scenario to assist in providing services in a safe and cautious manner.

**APPENDIX**

DATA

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bolted Fault Phase Currents at Bus 1 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 72.9516 | 22.7386 | 0 | 0 |  |  |  |
| Ib | 72.9516 | 0 | 63.6912 | 63.2709 |  |  |  |
| Ic | 72.9516 | 0 | 63.5513 | 63.2709 |  |  |  |
|  |  |  |  |  |  |  |  |
| Bolted Fault Phase Currents at Bus 2 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 72.9246 | 133.0052 | 0 | 0 |  |  |  |
| Ib | 72.9246 | 0 | 377.7696 | 63.2455 |  |  |  |
| Ic | 72.9246 | 0 | 375.7434 | 63.2455 |  |  |  |
|  |  |  |  |  |  |  |  |
| Bolted Fault Phase Currents at Bus 3 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 60.7861 | 146.7246 | 0 | 0 |  |  |  |
| Ib | 60.7861 | 0 | 577.1212 | 68.519 |  |  |  |
| Ic | 60.7861 | 0 | 570.4183 | 68.519 |  |  |  |
|  |  |  |  |  |  |  |  |
| Bolted Fault Phase Currents at Bus 4 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 23.2904 | 14.9477 | 0 | 0 |  |  |  |
| Ib | 23.2904 | 0 | 21.5463 | 20.5316 |  |  |  |
| Ic | 23.2904 | 0 | 20.776 | 20.5316 |  |  |  |
|  |  |  |  |  |  |  |  |
| Bolted Fault Phase Currents at Bus 5 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 23.0294 | 15.6001 | 0 | 0 |  |  |  |
| Ib | 23.0294 | 0 | 21.3794 | 20.2869 |  |  |  |
| Ic | 23.0294 | 0 | 20.6727 | 20.2869 |  |  |  |
|  |  |  |  |  |  |  |  |
| Bolted Fault Phase Currents at Bus 6 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 17.7973 | 12.2407 | 0 | 0 |  |  |  |
| Ib | 17.7973 | 0 | 16.7514 | 15.8293 |  |  |  |
| Ic | 17.7973 | 0 | 16.0027 | 15.8293 |  |  |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when 3PH Fault at Bus 1 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.2483 | 2.173 | 0.9582 | 0.7635 | 0.9869 | 0.2792 | 0.0741 |
| Ib | 0.2483 | 2.173 | 0.9582 | 0.7635 | 0.9869 | 0.2792 | 0.0741 |
| Ic | 0.2483 | 2.173 | 0.9582 | 0.7635 | 0.9869 | 0.2792 | 0.0741 |
|  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Phase Currents from Gen when 3PH Fault at Bus 1 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 10.3692 | 0.9582 | 1.7492 | 0 | 0 | 0 |  |
| Ib | 10.3692 | 0.9582 | 1.7492 | 0 | 0 | 0 |  |
| Ic | 10.3692 | 0.9582 | 1.7492 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when SLG Fault at Bus 1 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.7444 | 4.6254 | 1.2857 | 0.9738 | 1.0375 | 0.6812 | 0.0196 |
| Ib | 1.74 | 3.5132 | 0.7554 | 0.3005 | 0.6776 | 0.7074 | 0.4607 |
| Ic | 1.5242 | 3.4877 | 0.7706 | 0.4682 | 0.6644 | 0.6149 | 0.482 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when SLG Fault at Bus 1 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 7.2661 | 1.2857 | 2.0099 | 0 | 0 | 0 |  |
| Ib | 5.1489 | 0.7554 | 0.8859 | 0 | 0 | 0 |  |
| Ic | 4.8969 | 0.7706 | 1.0378 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when DLG Fault at Bus 1 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 1.5201 | 2.2774 | 0.6366 | 0.1238 | 0.6203 | 0.5059 | 0.4799 |
| Ib | 0.2709 | 3.0953 | 1.0851 | 0.8124 | 0.9717 | 0.3945 | 0.0717 |
| Ic | 0.6788 | 3.4877 | 1.0774 | 0.8743 | 1.0416 | 0.5404 | 0.0408 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when DLG Fault at Bus 1 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 3.797 | 0.6366 | 0.7242 | 0 | 0 | 0 |  |
| Ib | 11.7432 | 1.0851 | 1.7836 | 0 | 0 | 0 |  |
| Ic | 6.9834 | 1.0774 | 1.9084 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when LL Fault at Bus 1 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.8143 | 0.0602 | 0.8959 | 0.3543 | 0.7201 | 0.1177 | 0.36 |
| Ib | 0.9173 | 3.6108 | 1.001 | 0.9936 | 1.1175 | 0.5599 | 0.2334 |
| Ic | 0.6765 | 3.5944 | 0.9667 | 1.0707 | 1.1647 | 0.4911 | 0.2721 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when LL Fault at Bus 1 | | | |  |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.7595 | 0.8959 | 1.0734 | 0 | 0 | 0 |  |
| Ib | 17.4698 | 1.001 | 2.099 | 0 | 0 | 0 |  |
| Ic | 18.1677 | 0.9667 | 2.2332 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Non Bolted Fault Phase Currents at Bus 1 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 10.3858 | 5.1006 | 0 | 0 |  |  |  |
| Ib | 10.3858 | 0 | 8.9664 | 17.4574 |  |  |  |
| Ic | 10.3858 | 0 | 9.3335 | 17.4574 |  |  |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when 3PH Fault at Bus 2 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.875 | 2.055 | 0.2854 | 0.6384 | 1.1053 | 0.4735 | 0.0679 |
| Ib | 0.875 | 2.055 | 0.2854 | 0.6384 | 1.1053 | 0.4735 | 0.0679 |
| Ic | 0.875 | 2.055 | 0.2854 | 0.6384 | 1.1053 | 0.4735 | 0.0679 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when 3PH Fault at Bus 2 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 2.906 | 10.104 | 1.7437 | 0 | 0 | 0 |  |
| Ib | 2.906 | 10.104 | 1.7437 | 0 | 0 | 0 |  |
| Ic | 2.906 | 10.104 | 1.7437 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when SLG Fault at Bus 2 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.8446 | 0.6204 | 0.6725 | 0.4341 | 0.8342 | 0.222 | 0.2384 |
| Ib | 0.7725 | 0.3626 | 0.734 | 0.4442 | 0.816 | 0.1854 | 0.2862 |
| Ic | 0.8033 | 0.3598 | 0.8847 | 0.3847 | 0.7593 | 0.1211 | 0.3236 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when SLG Fault at Bus 2 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.4438 | 4.9448 | 1.2679 | 0 | 0 | 0 |  |
| Ib | 1.0545 | 0.734 | 1.2585 | 0 | 0 | 0 |  |
| Ic | 0.869 | 0.8847 | 1.1439 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when DLG Fault at Bus 2 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.7939 | 0.1984 | 0.7814 | 0.4122 | 0.7895 | 0.1533 | 0.2838 |
| Ib | 0.8768 | 1.7873 | 0.6583 | 0.5552 | 0.9976 | 0.3921 | 0.2141 |
| Ic | 0.8448 | 1.775 | 0.2269 | 0.6219 | 1.0674 | 0.44 | 0.1543 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when DLG Fault at Bus 2 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.9773 | 0.7814 | 1.2014 | 0 | 0 | 0 |  |
| Ib | 2.5022 | 8.7389 | 1.5524 | 0 | 0 | 0 |  |
| Ic | 2.6077 | 9.0601 | 1.6883 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when LL Fault at Bus 2 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.8141 | 0.0602 | 0.8957 | 0.3545 | 0.7203 | 0.1177 | 0.3598 |
| Ib | 0.9175 | 3.496 | 0.9078 | 0.7882 | 1.3031 | 0.6966 | 0.4208 |
| Ic | 0.8825 | 3.5128 | 0.6034 | 0.8529 | 1.3698 | 0.7483 | 0.4442 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when LL Fault at Bus 2 | | | |  |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.7593 | 0.8957 | 1.0738 | 0 | 0 | 0 |  |
| Ib | 4.2648 | 16.8567 | 2.0905 | 0 | 0 | 0 |  |
| Ic | 4.3617 | 17.7376 | 2.2219 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Non Bolted Fault Phase Currents at Bus 2 | | | |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 10.3856 | 5.2446 | 0 | 0 |  |  |  |
| Ib | 10.3856 | 0 | 9.3964 | 17.4566 |  |  |  |
| Ic | 10.3856 | 0 | 8.9243 | 17.4566 |  |  |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when 3PH Fault at Bus 3 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 1.4447 | 0.0629 | 1.5155 | 0.4186 | 0.3282 | 0.1088 | 0.9812 |
| Ib | 1.4447 | 0.0629 | 1.5155 | 0.4186 | 0.3282 | 0.1088 | 0.9812 |
| Ic | 1.4447 | 0.0629 | 1.5155 | 0.4186 | 0.3282 | 0.1088 | 0.9812 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when 3PH Fault at Bus 3 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.3862 | 1.5155 | 9.8152 | 0 | 0 | 0 |  |
| Ib | 1.3862 | 1.5155 | 9.8152 | 0 | 0 | 0 |  |
| Ic | 1.3862 | 1.5155 | 9.8152 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when SLG Fault at Bus 3 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.933 | 0.0371 | 1.0026 | 0.2665 | 0.6269 | 0.1202 | 0.4744 |
| Ib | 0.9017 | 0.0714 | 0.9879 | 0.2359 | 0.6004 | 0.1085 | 0.4443 |
| Ic | 0.8718 | 0.0803 | 0.9569 | 0.3689 | 0.7222 | 0.122 | 0.4385 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Phase Currents from Gen when SLG Fault at Bus 3 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.9017 | 1.0026 | 4.7319 | 0 | 0 | 0 |  |
| Ib | 0.8308 | 0.9879 | 0.8359 | 0 | 0 | 0 |  |
| Ic | 0.8036 | 0.9569 | 1.0825 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when DLG Fault at Bus 3 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 1.0156 | 0.0773 | 1.1003 | 0.2083 | 0.5427 | 0.1125 | 0.5653 |
| Ib | 1.2202 | 0.0602 | 1.2905 | 0.3829 | 0.5545 | 0.1222 | 0.7826 |
| Ic | 1.2483 | 0.0516 | 1.32 | 0.1492 | 0.2628 | 0.104 | 0.7771 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when DLG Fault at Bus 3 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.9426 | 1.1003 | 0.7298 | 0 | 0 | 0 |  |
| Ib | 1.1685 | 1.2905 | 8.4774 | 0 | 0 | 0 |  |
| Ic | 1.1983 | 1.32 | 8.8539 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when LL Fault at Bus 3 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 1.0901 | 0.0614 | 1.1671 | 0.1429 | 0.4598 | 0.1119 | 0.6292 |
| Ib | 1.6272 | 0.0634 | 1.693 | 0.7156 | 0.6103 | 0.1176 | 1.1836 |
| Ic | 1.6412 | 0.064 | 1.7079 | 0.5728 | 0.1828 | 0.0913 | 1.1612 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when LL Fault at Bus 3 | | | |  |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.034 | 1.1671 | 0.5643 | 0 | 0 | 0 |  |
| Ib | 1.5656 | 1.693 | 16.9373 | 0 | 0 | 0 |  |
| Ic | 1.5876 | 1.7079 | 17.3483 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Non Bolted Fault Phase Currents at Bus 3 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 10.3265 | 5.2442 | 0 | 0 |  |  |  |
| Ib | 10.3265 | 0 | 9.325 | 17.5352 |  |  |  |
| Ic | 10.3265 | 0 | 9.0064 | 17.5352 |  |  |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when 3PH Fault at Bus 4 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 4.1854 | 0.3761 | 2.8194 | 2.7441 | 1.8567 | 3.1084 | 0.8733 |
| Ib | 4.1854 | 0.3761 | 2.8194 | 2.7441 | 1.8567 | 3.1084 | 0.8733 |
| Ic | 4.1854 | 0.3761 | 2.8194 | 2.7441 | 1.8567 | 3.1084 | 0.8733 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when 3PH Fault at Bus 4 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 3.8112 | 2.8194 | 4.5994 | 9.1538 | 0 | 0 |  |
| Ib | 3.8112 | 2.8194 | 4.5994 | 9.1538 | 0 | 0 |  |
| Ic | 3.8112 | 2.8194 | 4.5994 | 9.1538 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when SLG Fault at Bus 4 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 3.1889 | 1.4237 | 2.5044 | 2.5506 | 1.7704 | 2.7988 | 0.8269 |
| Ib | 0.8846 | 1.2105 | 0.9568 | 0.7842 | 0.7237 | 1.3573 | 0.6978 |
| Ic | 0.6401 | 1.1559 | 0.6545 | 0.8343 | 0.53 | 1.2918 | 0.7947 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when SLG Fault at Bus 4 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.7664 | 2.5044 | 4.3176 | 4.6805 | 0 | 0 |  |
| Ib | 1.1 | 0.9568 | 1.2878 | 0 | 0 | 0 |  |
| Ic | 1.1009 | 0.6545 | 1.1762 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when DLG Fault at Bus 4 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.3976 | 0.7543 | 0.4996 | 0.3165 | 0.3983 | 0.9536 | 0.7344 |
| Ib | 3.9141 | 0.9204 | 2.702 | 2.7296 | 1.8328 | 3.0865 | 0.9062 |
| Ic | 3.8334 | 0.9697 | 2.7001 | 2.6899 | 1.875 | 2.9387 | 0.8579 |
|  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Phase Currents from Gen when DLG Fault at Bus 4 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.1393 | 0.4996 | 0.0822 | 0 | 0 | 0 |  |
| Ib | 3.3505 | 2.702 | 4.5601 | 8.2621 | 0 | 0 |  |
| Ic | 3.2772 | 2.7001 | 4.5634 | 7.947 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when LL Fault at Bus 4 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.8789 | 0.0605 | 0.9594 | 0.2722 | 0.6405 | 0.1144 | 0.417 |
| Ib | 5.538 | 0.5167 | 3.5641 | 3.82 | 2.4005 | 4.4835 | 1.4551 |
| Ic | 5.2788 | 0.4778 | 3.2987 | 3.7591 | 2.2255 | 4.4764 | 1.6532 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when LL Fault at Bus 4 | | | |  |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.8252 | 0.9594 | 0.9124 | 0 | 0 | 0 |  |
| Ib | 5.0238 | 3.5641 | 6.2132 | 13.0347 | 0 | 0 |  |
| Ic | 4.8013 | 3.2987 | 5.9779 | 13.0347 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Non Bolted Fault Phase Currents at Bus 4 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 9.1538 | 4.6805 | 0 | 0 |  |  |  |
| Ib | 9.1538 | 0 | 8.2621 | 13.0347 |  |  |  |
| Ic | 9.1538 | 0 | 7.947 | 13.0347 |  |  |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when 3PH Fault at Bus 5 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 2.7243 | 0.2749 | 4.2738 | 1.5978 | 2.9283 | 3.3731 | 1.9904 |
| Ib | 2.7243 | 0.2749 | 4.2738 | 1.5978 | 2.9283 | 3.3731 | 1.9904 |
| Ic | 2.7243 | 0.2749 | 4.2738 | 1.5978 | 2.9283 | 3.3731 | 1.9904 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when 3PH Fault at Bus 5 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 2.9983 | 4.2738 | 4.5261 | 0 | 0 | 0 |  |
| Ib | 2.9983 | 4.2738 | 4.5261 | 0 | 0 | 0 |  |
| Ic | 2.9983 | 4.2738 | 4.5261 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when SLG Fault at Bus 5 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 2.0997 | 0.6055 | 3.769 | 1.5219 | 2.6208 | 2.7398 | 1.7643 |
| Ib | 0.8077 | 0.7267 | 1.1722 | 0.4341 | 0.8021 | 0.8548 | 1.0591 |
| Ic | 0.6054 | 0.6678 | 0.9596 | 0.4249 | 0.6341 | 0.9398 | 1.1153 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when SLG Fault at Bus 5 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.4974 | 3.769 | 4.1426 | 0 | 0 | 0 |  |
| Ib | 0.9932 | 1.1722 | 1.2294 | 0 | 0 | 0 |  |
| Ic | 0.9979 | 0.9596 | 1.0487 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when DLG Fault at Bus 5 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.6273 | 0.4321 | 0.1632 | 0.0158 | 0.2017 | 0.5307 | 0.9766 |
| Ib | 2.5434 | 0.4987 | 4.1709 | 1.6014 | 2.8627 | 3.3062 | 2.0575 |
| Ic | 2.4926 | 0.5249 | 4.0223 | 1.5955 | 2.8552 | 3.0644 | 1.8259 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when DLG Fault at Bus 5 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.0488 | 0.1632 | 0.1866 | 0 | 0 | 0 |  |
| Ib | 2.651 | 4.1709 | 4.4637 | 0 | 0 | 0 |  |
| Ic | 2.5738 | 4.0223 | 4.4507 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when LL Fault at Bus 5 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.8761 | 0.0605 | 0.9566 | 0.275 | 0.6432 | 0.1145 | 0.4142 |
| Ib | 3.4608 | 0.4057 | 5.6204 | 2.1838 | 3.9149 | 4.736 | 3.042 |
| Ic | 3.2042 | 0.4519 | 5.3416 | 2.1154 | 3.7316 | 4.7415 | 3.216 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when LL Fault at Bus 5 | | | |  |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.8225 | 0.9566 | 0.9181 | 0 | 0 | 0 |  |
| Ib | 3.8658 | 5.6204 | 6.0986 | 0 | 0 | 0 |  |
| Ic | 3.6407 | 5.3416 | 5.8465 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Non Bolted Fault Phase Currents at Bus 5 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 9.1024 | 4.6989 | 0 | 0 |  |  |  |
| Ib | 9.1024 | 0 | 8.2523 | 12.9332 |  |  |  |
| Ic | 9.1024 | 0 | 7.8721 | 12.9332 |  |  |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when 3PH Fault at Bus 6 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 2.1442 | 0.1569 | 3.1286 | 0.9366 | 4.7048 | 2.1223 | 4.6731 |
| Ib | 2.1442 | 0.1569 | 3.1286 | 0.9366 | 4.7048 | 2.1223 | 4.6731 |
| Ic | 2.1442 | 0.1569 | 3.1286 | 0.9366 | 4.7048 | 2.1223 | 4.6731 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when 3PH Fault at Bus 6 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 2.2956 | 3.1286 | 5.6399 | 0 | 0 | 0 |  |
| Ib | 2.2956 | 3.1286 | 5.6399 | 0 | 0 | 0 |  |
| Ic | 2.2956 | 3.1286 | 5.6399 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Phase Currents through lines when SLG Fault at Bus 6 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 1.6278 | 0.3745 | 2.6817 | 1.0401 | 4.2612 | 1.7381 | 3.895 |
| Ib | 0.8514 | 0.4509 | 1.0326 | 0.3876 | 1.3024 | 0.5026 | 1.3407 |
| Ic | 0.6525 | 0.3757 | 0.5806 | 0.2744 | 1.1047 | 0.5424 | 1.0755 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when SLG Fault at Bus 6 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 1.2599 | 2.6817 | 5.2974 | 0 | 0 | 0 |  |
| Ib | 0.8909 | 1.0326 | 1.6316 | 0 | 0 | 0 |  |
| Ic | 0.9362 | 0.5806 | 1.3437 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when DLG Fault at Bus 6 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.7656 | 0.2477 | 0.5321 | 0.0824 | 0.2924 | 0.2705 | 0.5116 |
| Ib | 1.9906 | 0.287 | 3.0028 | 1.0011 | 4.6992 | 2.067 | 4.5589 |
| Ic | 1.9377 | 0.3315 | 2.9315 | 1.0006 | 4.5131 | 1.9587 | 4.2703 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when DLG Fault at Bus 6 | | | | |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.987 | 0.5321 | 0.2365 | 0 | 0 | 0 |  |
| Ib | 2.0622 | 3.0028 | 5.694 | 0 | 0 | 0 |  |
| Ic | 1.9398 | 2.9315 | 5.5136 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Phase Currents through lines when LL Fault at Bus 6 | | | | |  |  |  |
|  | Line1 | Line2 | Line3 | Line4 | Line5 | Line6 | Line7 |
| Ia | 0.8901 | 0.0606 | 0.9702 | 0.2558 | 0.6237 | 0.1133 | 0.4262 |
| Ib | 2.5135 | 0.2135 | 3.7951 | 1.2246 | 6.113 | 2.7786 | 6.0271 |
| Ic | 2.2095 | 0.2679 | 3.4407 | 1.1157 | 5.8535 | 2.7664 | 5.8233 |
|  |  |  |  |  |  |  |  |
| Phase Currents from Gen when LL Fault at Bus 6 | | | |  |  |  |  |
|  | Bus1 | Bus2 | Bus3 | Bus4 | Bus5 | Bus6 |  |
| Ia | 0.837 | 0.9702 | 0.8795 | 0 | 0 | 0 |  |
| Ib | 2.7267 | 3.7951 | 7.3359 | 0 | 0 | 0 |  |
| Ic | 2.446 | 3.4407 | 6.9683 | 0 | 0 | 0 |  |
|  |  |  |  |  |  |  |  |
| Non Bolted Fault Phase Currents at Bus 6 | | | |  |  |  |  |
|  | 3PH | SLG | DLG | LL |  |  |  |
| Ia | 8.5423 | 4.487 | 0 | 0 |  |  |  |
| Ib | 8.5423 | 0 | 7.8155 | 11.3559 |  |  |  |
| Ic | 8.5423 | 0 | 7.3783 | 11.3559 |  |  |  |

CODE

Outputting Results Script:

% EE 455 Fault Current Calculation

%

% Matrix methods problem data

%

%

% Number of transmission lines, nline

%

nline = 7;

%

% Number of buses, nbus

%

nbus = 6;

%

% Line resistances, R

%

R = zeros(1, nline);

%

% Line reactances, X

%

X = [ 0.10 0.05 0.10 0.14 0.10 0.05 0.05 ];

%

% Line admittances, G and B

%

G = zeros(1, nline); %Create the arrays in the proper size

B = zeros(1, nline);

for line = 1:nline

zsquared = R(line)\*R(line) + X(line)\*X(line);

G(line) = R(line) / zsquared;

B(line) = -X(line) / zsquared;

end

%

% Line charging, BC (Half total charging, in p.u. VARs)

%

BC = zeros(1, nline);

%

% Transmission line buses:

% F - From end buses

% T - To end buses

%

F = [ 1 1 2 3 3 4 5 ];

T = [ 4 2 5 4 6 5 6 ];

%

% Load at each bus, per unit, 100MVA base

% Pload - Real load, p.u. Watts

% Qload - Reactive load, p.u. VAR

%

Pload = [ 0.0 0.0 0.0 1.0 0.5 1.1 ];

Qload = [ 0.0 0.0 0.0 0.4 0.3 0.4 ];

%

% Generator real power at each bus, p.u. Watts, Pgen

%

Pgen = [ 0.7 0.9 1.0 0.0 0.0 0.0 ];

%

% Generator sequence reactances, per unit

% Xgenplus - Positive Sequence

% Xgenminus - Negative Sequence

% Xgenzero - Zero Sequence (does NOT include the effects of ground connections)

% Groundgen - 1 if generator is grounded Y, else 0

%

Xgenplus = [ 0.02 0.02 0.02 0.0 0.0 0.0 ];

Xgenminus = [ 0.02 0.02 0.01 0.0 0.0 0.0 ];

Xgenzero = [ 0.005 0.005 0.005 0.0 0.0 0.0 ];

Groundgen = [ 0 1 1 0 0 0 ];

%

% Prefault voltages (p.u. Volts)

% Vprefault - Magnitude

% Thetapfd - Angle, degrees

% Thetapf - Angle, radians

%

Vprefault = [ 1.050 1.050 1.050 1.021 1.017 1.015 ];

Thetapfd = [ 0.0 0.164 -1.645 -4.083 -4.328 -5.278 ];

Thetapf = Thetapfd \* pi / 180.0;

%Set "small" and "large" values and inital Zg

small = 10^-7;

large = 10^8;

Zg = small;

%A matrix used in multiple functions

alpha = exp(j\*2\*pi/3);

A = [1 1 1;1 alpha^2 alpha;1 alpha alpha^2];

%Building the Sequence components of Y matrix

YlineP = YBuild(B,T,F,nbus);

YgenP = YgenBuild(Xgenplus);

Yload = YloadBuild(Pload, Qload, Vprefault);

Ypos = j\*YlineP + j\*YgenP + Yload;

YlineN = YlineP;

YgenN = YgenBuild(Xgenminus);

Yneg = j\*YlineN + j\*YgenN + Yload;

YlineZ = YBuild(B/3,T,F,nbus);

YgenZ = YgenBuild(Xgenzero, Groundgen);

Yzer = j\*YlineZ + j\*YgenZ + Yload;

%Calculate Bolted Fault Currents from each Bus

for q = 1:nbus

Zsqq = ZSIQer(Yzer,Ypos,Yneg,q,q);

%3 phase

Ysf = YsfBuild(small,small,small,Zg, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = A\*Isf;

%SLG configurations

Ysf = YsfBuild(small,large,large,Zg, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = [If\_b A\*Isf];

%DLG configurations

Ysf = YsfBuild(large,small,small,Zg, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = [If\_b A\*Isf];

%LL configurations

Ysf = YsfBuild(large,small,small,large, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

['Bolted Fault Phase Currents at Bus ', num2str(q)]

If\_b = [If\_b A\*Isf;

magIf\_b = abs(If\_b)

end

%Not bolted fault impedance configurations

Zg = 0.1;

Za = 0.1;

Zb = 0.1;

Zc = 0.1;

%Calculate Non Bolted Fault Currents from each Bus

for q = 1:nbus

Zsqq = ZSIQer(Yzer,Ypos,Yneg,q,q);

%3 phase configurations

Ysf = YsfBuild(Za,Zb,Zc,Zg, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = A\*Isf;

Vbus = voltageBus(Isf, q, Vprefault, Thetapf, Yzer, Ypos, Yneg, A);

%Displays magnitudes of transmission line phase currents

['Phase Currents through lines when 3PH Fault at Bus ', num2str(q)]

Ilines = calclineI(Vbus, F, T, B);

magIlines = abs(Ilines)

['Phase Currents from Gen when 3PH Fault at Bus ', num2str(q)]

genI = calcigen(Ilines, If\_b(:,end), F, T, Pgen,q);

magGenI = abs(genI)

%SLG configurations

Ysf = YsfBuild(Za,large,large,Zg, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = [If\_b A\*Isf];

Vbus = voltageBus(Isf, q, Vprefault, Thetapf, Yzer, Ypos, Yneg, A);

%Displays magnitudes of transmission line phase currents

['Phase Currents through lines when SLG Fault at Bus ', num2str(q)]

Ilines = calclineI(Vbus, F, T, B);

magIlines = abs(Ilines)

['Phase Currents from Gen when SLG Fault at Bus ', num2str(q)]

genI = calcigen(Ilines, If\_b(:,end), F, T, Pgen,q);

magGenI = abs(genI)

%DLG configurations

Ysf = YsfBuild(large,Zb,Zc,Zg, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = [If\_b A\*Isf];

Vbus = voltageBus(Isf, q, Vprefault, Thetapf, Yzer, Ypos, Yneg, A);

%Displays magnitudes of transmission line phase currents

['Phase Currents through lines when DLG Fault at Bus ', num2str(q)]

Ilines = calclineI(Vbus, F, T, B);

magIlines = abs(Ilines)

['Phase Currents from Gen when DLG Fault at Bus ', num2str(q)]

genI = calcigen(Ilines, If\_b(:,end), F, T, Pgen,q);

magGenI = abs(genI)

%LL configurations

Ysf = YsfBuild(large,Zb/2,Zc/2,large, A);

Isf = Isfcalc(Ysf,Zsqq,Vprefault,Thetapf,q);

If\_b = [If\_b A\*Isf];

Vbus = voltageBus(Isf, q, Vprefault, Thetapf, Yzer, Ypos, Yneg,A);

%Displays magnitudes of transmission line phase currents

['Phase Currents through lines when LL Fault at Bus ', num2str(q)]

Ilines = calclineI(Vbus, F, T, B);

magIlines = abs(Ilines)

['Phase Currents from Gen when LL Fault at Bus ', num2str(q)]

genI = calcigen(Ilines, If\_b(:,end), F, T, Pgen,q);

magGenI = abs(genI)

%Displays magnitudes of fault phase currents for each type of fault

%arranged columns (3PH, SLG, DLG, LL)

['Non Bolted Fault Phase Currents at Bus ', num2str(q)]

magIf\_b= abs(If\_b)

end

List of functions:

function Isf = Isfcalc (Ysf, Zsqq, Vpf, Thetapf, q)

%Use relationship of Ysf, Zsqq and prefault Voltages to calculate the

%sequence fault currents Isf

Isf = Ysf\*inv(eye(3)+ Zsqq\*Ysf)\*[0;Vpf(q)\*exp(j\*Thetapf(q));0];

end

function Vbus = voltageBus(Isf, q, Vpf, Thetapf, Yzer, Ypos, Yneg, A)

%Calculates the Post fault phase voltages at every bus

Vbus = A\*([0;Vpf(1);0]\*exp(j\*Thetapf(1)) - ZSIQer(Yzer, Ypos, Yneg, 1 ,q)\*Isf);

for i = 2:length(Vpf)

Vbus = [Vbus A\*([0;Vpf(i);0]\*exp(j\*Thetapf(i)) - ZSIQer(Yzer, Ypos, Yneg, i ,q)\*Isf)];

end

end

function Zsiq = ZSIQer(Yzer, Ypos, Yneg, i ,q)

%Constructs the sequence impedance matrix Zsiq from the sequence

%Y matrix components

Zzer = inv(Yzer);

Zpos = inv(Ypos);

Zneg = inv(Yneg);

Zsiq = diag([Zzer(i,q) Zpos(i,q) Zneg(i,q)]);

end

function Yline = YBuild(Adm, To, Fro, nBus)

%Builds the line admittance matrix componet of sequence Y matrix

Yline = zeros(nBus);

for n = 1:length(Adm)

Yline(Fro(n),To(n))= -1.\*Adm(n);

end

Yline = Yline + Yline';

Yline = diag(-1\*sum(Yline)) + Yline;

end

function genI = calcigen(Ilines, iFault, F, T, Pgen, q)

%calculate the phase currents coming out of the generators in all the

%busses

genI = zeros(3,length(Pgen));

line = 0;

for i = 1:length(F)

if line ~= F(i)

if(line == q)

genI(:,line) = genI(:,line) + iFault;

end

line = line + 1;

end

if (Pgen(line) ~= 0)

genI(:,line) = genI(:,line) + Ilines(:,i);

end

end

end

function Ygen = YgenBuild (Imp, Gnded)

%Builds the sequence generator admittance component of sequence Y

%matrix

if nargin == 2

Ygen = (Imp.\*Gnded);

Ygen(Ygen ~= 0.0+j\*0.0) = 1./(Ygen((Ygen ~= 0.0+j\*0.0)));

Ygen = diag(Ygen);

elseif nargin == 1

Ygen = zeros(length(Imp));

Ygen = diag((-1./Imp));

Ygen(Ygen == -Inf) = 0.0+j\*0.0;

else

error('Must be 1 for Pos/Neg Seq or 2 arguements for Zero Seq')

end

end

function Ilines = calclineI(Vbus, F, T, B)

%calculates all the transmission lines phase currents

Ilines = zeros(3,length(T));

for i= 1:length(F)

Ilines(:,i) = (Vbus(:,F(i)) - Vbus (:,T(i)))\*B(i);

end

end

function Yload = YloadBuild (Pload, Qload, Vpf)

%Builds the sequence load admittance component of sequence Y matrix

Yload = (Vpf.^2./(Pload - j\*Qload)).^-1;

Yload = diag(Yload);

end

function Ysf = YsfBuild (Za, Zb, Zc, Zg,A)

%Constructs the sequence fault admittance matrix Ysf based on fault

%impedance configurations

Zf = [Za+Zg, Zg, Zg; Zg, Zb+Zg, Zg; Zg, Zg, Zc+Zg];

Yf = inv(Zf);

Ysf = inv(A)\*Yf\*A;

Zsf = inv(A)\*Zf\*A;

end