# Three Phase Balanced Fault Analysis of 6-Bus Power System using Power World Simulator

# Dr. Aung Zaw Latt

Department of Electrical Power Engineering, Technological University (Maubin), Maubin, Myanmar

*Abstract*— Electrical fault is the deviation of currents and voltages from nominal values or states. Under steady state operating conditions, power system lines or equipments carry normal voltages and currents which results in a safer operation of the system network. However when fault occurs, it causes excessively high currents to flow which causes the damage to equipments and devices. In this paper, Power World Simulator tool is employed to determine fault current distribution and bus voltage levels during three phase balanced fault conditions of 6-bus power system model in order to give information for the selection and coordination of suitable switchgear equipments, electromechanical relays, circuit breakers and other protection devices.

*Keywords*— fault analysis, three phase balanced fault, fault current, bus voltage, powerworld simulator

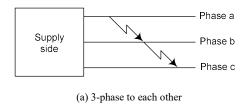
#### I. INTRODUCTION

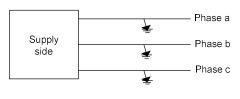
The steady state operating conditions of a power system is balanced three phase a.c. But, due to sudden internal or external changes in the system, this condition is disrupted. When the insulation the system fails at one or more points or a conducting object comes into contact with a live point, a short circuit or a fault occurs. Faults may lead to fire breakout that consequently results into loss of life, loss of property, cut of supply in areas beyond the fault point in a transmission and distribution network leading to power blackouts and destruction of a system network. All the above results into delayed development due to low gross product realised. Therefore, it is necessary to determine the values of system voltages and currents during three phase balanced fault conditions, so that protective devices may be located to detect and minimize the harmful effects. Three phase balanced faults may be analysed using an equivalent single phase circuit. Normally, fault analysis is calculated in per-unit quantities as they provide solutions which are somewhat consistent over different voltage and power ratings, and operate on values of the order of unity. The powerworld simulator tool can be employed to analyse the fault current distribution and bus voltages levels during unsymmetrical fault condition and allows for the easy simulation of bus systems. In this paper, the powerworld simulator tool is employed to analysis the three phase balanced fault of 6-bus power system model. Although this system model is a relatively small and simple power system, this system works will assist students in

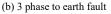
understanding fault analysis. The results of changes to the system can be seen quickly in Power World, further aiding students' learning process and utility engineers.

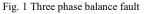
# A. Three Phase Balanced Fault

Three phase fault is a condition where either (a) all 3- phase are short circuited to each other, or (b) all 3-phase of the system are earth. This fault is a balanced condition and needed to only know the positive-sequence network to analyse the faults. Normally, only 5% of the initial faults in a power system, are three phase balanced fault with or without earth.









#### B. Description of Per Unit Quantities

Percentage quantities or per unit quantities are actually fractional quantities of a reference quantity. These have a lot of significance as per unit quantities of parameters tend to have similar values even when the voltage and rating change drastically. Per unit system allows multiplication and division in addition to addition and subtraction without the requirement of a correction factor. Per-unit values are noted that "pu" after the value. For power, current, voltage and impedance, the p.u quantity may be calculated by dividing by the respective base of that quantity. Expressions such as Ohm's Law can be used for per unit quantities as well. Since power, voltage, current and impedance are linked; only reference quantities or two base can be independently defined. The base quantities for the other two can be calculated there from.

$$S_{pu} = \frac{S}{S_{base}}$$
,  $V_{pu} = \frac{V}{V_{base}}$ ,  $I_{pu} = \frac{I}{I_{base}}$ ,  $Z_{pu} = \frac{Z}{Z_{base}}$ 

# C. Description of PowerWorld Simulator to Fault Analysis

Fault analysis can be better understood by using PowerWorld simulator tool. This simulator tool allow for the easy simulation of bus systems that would take a significant amount of time if done by hand calculation. One such system is 6-bus power system model. PowerWorld's extensive range of products give the tools needed by transmission planners, system operators and trainers, educators, power marketers, and anyone else desiring access to power system information and analysis in a user friendly format. The single line diagrams are calculated for the benefit of the users. The integrated drawing tools provide an easy and fast approach to creating single line diagrams where a single line is described to represent three phases of a power system.

# II. THREE PHASE BALANCED FAULT ANALYSIS RESULTS USING POWERWORLD SIMULATOR

#### A. Input Data of 6-Bus Power System Model

Fig. 2 shows single line diagram of 6-bus power system model under steady state condition by using powerworld simulator.Input data for the Simulator include synchronous generator, load and transmission line data as illustrated in Tables I, and II . Let's the prefault voltage  $V_F = 1.0 \angle 0$  H, fault impedance  $Z_F = 0$  and bus 1 is slack bus.

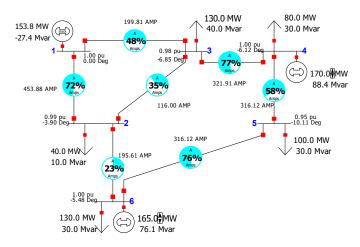


Fig. 2 Single Line Diagram of 6-bus power system under steady state condition

$$(S_{base} = 100 \text{ MVA}, P_{base} = 100 \text{ MW})$$

TABLE I

generators & loads input data of 6-bus power system model

| Bus | V<br>p.u | δ<br>p.u | $P_{G}$ | $Q_{G}$ | $P_{L}$ | $Q_L$ |
|-----|----------|----------|---------|---------|---------|-------|
| 1   | 1.0      | 0        | -       | -       | 0       | 0     |
| 2   | -        | -        | 0       | 0       | 0.4     | 0.1   |

| 3 | - | - | 0    | 0 | 1.3 | 0.4 |
|---|---|---|------|---|-----|-----|
| 4 | 1 | - | 1.7  | 0 | 0.8 | 0.3 |
| 5 | - | - | 0    | 0 | 1   | 0.3 |
| 6 | 1 | - | 1.65 | 0 | 1.3 | 0.3 |

#### TABLE II

TRANSMISSION LINES INPUT DATA OF 6- BUS POWER SYSTEM MODEL

| Bus to Bus | R    | Х    | В    | Max MVA |
|------------|------|------|------|---------|
| Dus to Dus | p.u  | p.u  | p.u  | p.u     |
| 1-2        | 0.02 | 0.06 | 0.06 | 1       |
| 1-3        | 0.08 | 0.24 | 0.05 | 1       |
| 2-3        | 0.06 | 0.18 | 0.04 | 1       |
| 2-6        | 0.02 | 0.06 | 0.05 | 1       |
| 3 - 4      | 0.01 | 0.03 | 0.02 | 1       |
| 4-5        | 0.08 | 0.24 | 0.05 | 1       |
| 5-6        | 0.04 | 0.12 | 0.03 | 1       |

B. Three Phase Balanced Fault Analysis Results of 6-Bus Power System Model (Case Study I – Bus fault)

After three phase balanced fault type is selected in fault analysis dialog at run mode condition, three phase balanced fault is calculated consist of the fault current in each phase, contributions to the fault current from each branch connected to the fault bus for each phase and the voltages for a fault at bus 1, bus 2, bus 3, bus 4, bus 5 and bus 6. Three phase balanced fault analysis results are shown in Table III and IV.

TABLE III

|              | Subtra | ansient C | urrent  |        | Fault   | Current |         |
|--------------|--------|-----------|---------|--------|---------|---------|---------|
| Fault<br>Bus | (Pha   | se A,B ar | nd C)   | Bus    | Phase A | Phase B | Phase C |
|              | p.u    | Amp       | Deg     | To Bus | p.u     | p.u     | p.u     |
| 1            | 4.950  | 2071      | -52.15  | 1-2    | 2.46847 | 2.46847 | 2.46847 |
|              | 4.950  | 2071      | -172.15 | 1-3    | 1.05069 | 1.05069 | 1.05069 |
|              | 4.950  | 2071      | 67.85   | 2 – 3  | 0.58151 | 0.58151 | 0.58151 |
|              |        |           |         | 2-6    | 1.9203  | 1.9203  | 1.9203  |
|              |        |           |         | 3 – 4  | 1.86002 | 1.86002 | 1.86002 |
|              |        |           |         | 4-5    | 0.19663 | 0.19663 | 0.19663 |
|              |        |           |         | 5 - 6  | 0.17662 | 0.17662 | 0.17662 |
| 2            | 5.346  | 2236      | -50.63  | 1-2    | 1.88535 | 1.88535 | 1.88535 |
|              | 5.346  | 2236      | -170.6  | 1-3    | 0.47586 | 0.47586 | 0.47586 |
|              | 5.346  | 2236      | 69.37   | 2 – 3  | 1.15685 | 1.15685 | 1.15685 |
|              |        |           |         | 2-6    | 2.39686 | 2.39686 | 2.39686 |
|              |        |           |         | 3 – 4  | 1.76407 | 1.76407 | 1.76407 |
|              |        |           |         | 4-5    | 0.36582 | 0.36582 | 0.36582 |
|              |        |           |         | 5 - 6  | 0.26406 | 0.26406 | 0.26406 |
| 3            | 5.339  | 2233      | -50.90  | 1-2    | 0.62149 | 0.62149 | 0.62149 |
|              | 5.339  | 2233      | -170.9  | 1-3    | 1.06686 | 1.06686 | 1.06686 |

www.rsisinternational.org

| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 1.33071         1.22883         2.95954 |
|---|---|
| 2-6<br>3-4 2.95954 2.95954<br>0.56275 0.56275           |   |
|   | 2.95954                                 |
| 4-5 0.56275 0.56275                                     |   |
|   | 0.56275                                 |
| 5-6 0.74258 0.74258                                     | 0.74258                                 |
| 4 5.407 2262 -51.58 1-2 0.66239 0.66239                 | 0.66239                                 |
| 5.407 2262 -171.6 1-3 0.94804 0.94804                   | 0.94804                                 |
| 5.407 2262 68.42 2 - 3 1.14077 1.14077                  | 1.14077                                 |
| 2-6 0.97551 0.97551                                     | 0.97551                                 |
| 3-4 2.0436 2.0436                                       | 2.0436                                  |
| 4-5 0.84035 0.84035                                     | 0.84035                                 |
| 5-6 0.999 0.999   | 0.999                                   |
| 5 4.428 1852 -54.89 1-2 1.06254 1.06254                 | 1.06254                                 |
| 4.428 1852 -174.9 1-3 0.34616 0.34616                   | 0.34616                                 |
| 4.428 1852 65.11 2-3 0.21816 0.21816                    | 0.21816                                 |
| 2-6 0.91927 0.91927                                     | 0.91927                                 |
| 3-4 0.2431 0.2431                                       | 0.2431                                  |
| 4-5 1.66913 1.66913                                     | 1.66913                                 |
| 5-6 2.75103 2.75103                                     | 2.75103                                 |
| 6 5.435 2273 -50.51 1-2 1.56815 1.56815                 | 1.56815                                 |
| 5.435 2273 -170.5 1-3 0.33736 0.33736                   | 0.33736                                 |
| 5.435 2273 69.49 2-3 0.77988 0.77988                    | 0.77988                                 |
| 2-6 2.23882 2.23882                                     | 2.23882                                 |
| 3-4 1.19928 1.19928                                     | 1.19928                                 |
| 4-5 0.86584 0.86584                                     | 0.86584                                 |
| 5-6 0.8021 0.8021                                       | 0.8021                                  |

#### TABLE IV

BUS RESULTS DATA OF 6- BUS POWER SYSTEM MODEL

| $V_{prefault}$ =1.0 $\ge 0$ |     | Bus Voltages during Fault |         |         |  |  |  |
|-----------------------------|-----|---------------------------|---------|---------|--|--|--|
| Fault Bus                   | Bus | Phase A                   | Phase B | Phase C |  |  |  |
| 1                           | 1   | 0.00000                   | 0.00000 | 0.00000 |  |  |  |
|                             | 2   | 0.15612                   | 0.15612 | 0.15612 |  |  |  |
|                             | 3   | 0.26581                   | 0.26581 | 0.26581 |  |  |  |
|                             | 4   | 0.32394                   | 0.32394 | 0.32394 |  |  |  |
|                             | 5   | 0.27716                   | 0.27716 | 0.27716 |  |  |  |
|                             | 6   | 0.27727                   | 0.27727 | 0.27727 |  |  |  |
| 2                           | 1   | 0.11945                   | 0.11945 | 0.11945 |  |  |  |
|                             | 2   | 0.00000                   | 0.00000 | 0.00000 |  |  |  |
|                             | 3   | 0.2195                    | 0.2195  | 0.2195  |  |  |  |
|                             | 4   | 0.27518                   | 0.27518 | 0.27518 |  |  |  |
|                             | 5   | 0.18248                   | 0.18248 | 0.18248 |  |  |  |
|                             | 6   | 0.15159                   | 0.15159 | 0.15159 |  |  |  |
| 3                           | 1   | 0.27153                   | 0.27153 | 0.27153 |  |  |  |
|                             | 2   | 0.2534                    | 0.2534  | 0.2534  |  |  |  |

|   | 3 | 0.00000 | 0.00000 | 0.00000 |
|---|---|---------|---------|---------|
|   | 4 | 0.09359 | 0.09359 | 0.09359 |
|   | 5 | 0.23523 | 0.23523 | 0.23523 |
|   | 6 | 0.32601 | 0.32601 | 0.32601 |
| 4 | 1 | 0.30594 | 0.30594 | 0.30594 |
|   | 2 | 0.28208 | 0.28208 | 0.28208 |
|   | 3 | 0.06464 | 0.06464 | 0.06464 |
|   | 4 | 0.00000 | 0.00000 | 0.00000 |
|   | 5 | 0.21259 | 0.21259 | 0.21259 |
|   | 6 | 0.33691 | 0.33691 | 0.33691 |
| 5 | 1 | 0.46409 | 0.46409 | 0.46409 |
|   | 2 | 0.405   | 0.405   | 0.405   |
|   | 3 | 0.41728 | 0.41728 | 0.41728 |
|   | 4 | 0.42481 | 0.42481 | 0.42481 |
|   | 5 | 0.00000 | 0.00000 | 0.00000 |
|   | 6 | 0.34798 | 0.34798 | 0.34798 |
| 6 | 1 | 0.24007 | 0.24007 | 0.24007 |
|   | 2 | 0.14181 | 0.14181 | 0.14181 |
|   | 3 | 0.28436 | 0.28436 | 0.28436 |
|   | 4 | 0.32215 | 0.32215 | 0.32215 |
|   | 5 | 0.10164 | 0.10164 | 0.10164 |
|   | 6 | 0.00000 | 0.00000 | 0.00000 |
|   |   |         |         |         |

# B. Three Phase Balanced Fault Analysis Results of 6-Bus Power System Model (Case Study II- In line fault)

After three phase balanced fault type is selected in fault analysis dialog at run mode condition, three phase balanced fault is calculated consist of the fault current in each phase, contributions to the fault current from each branch connected to the bus for each phase and the voltages for a fault in transmission lines. Three phase balanced fault analysis results are shown in Table III and IV.

TABLE V

| Line<br>Fault     | Subtransient Current |      |                           | Eault current |        |        |        |  |  |
|-------------------|----------------------|------|---------------------------|---------------|--------|--------|--------|--|--|
| (50 %<br>location | (Phase A, B and C)   |      | (Phase A, B and C) Bus to | Bus to        | Phase  | Phase  | Phase  |  |  |
| between           |                      |      |                           |               | А      | В      | С      |  |  |
| lines)            | p.u                  | Amp  | Deg                       | Bus           | p.u    | p.u    | p.u    |  |  |
| 1-2               | 5.075                | 2123 | -51.77                    | 1-2           | 0.0000 | 0.0000 | 0.0000 |  |  |
|                   | 5.075                | 2123 | 171.78                    | 1-3           | 0.7585 | 0.7585 | 0.7585 |  |  |
|                   | 5.075                | 2123 | 68.23                     | 1 – Fault     | 2.2273 | 2.2273 | 2.2273 |  |  |
|                   |                      |      |                           | 2-3           | 0.8465 | 0.8465 | 0.8465 |  |  |
|                   |                      |      |                           | 2-6           | 2.1259 | 2.1259 | 2.1259 |  |  |
|                   |                      |      |                           | Fault-2       | 2.9520 | 2.9520 | 2.9520 |  |  |
|                   |                      |      |                           | 3 – 4         | 1.7998 | 1.7998 | 1.7998 |  |  |
|                   |                      |      |                           | 4-5           | 0.2762 | 0.2762 | 0.2762 |  |  |

|       |       |      |        |           | 1      | 1      |        |
|-------|-------|------|--------|-----------|--------|--------|--------|
|       |       |      |        | 5-6       | 0.1817 | 0.1817 | 0.1817 |
| 1-3   | 4.344 | 1817 | -55.5  | 1-2       | 1.1615 | 1.1615 | 1.1615 |
|       | 4.344 | 1817 | -175.5 | 1-2       | 0.0000 | 0.0000 | 0.0000 |
|       | 4.344 | 1817 | 64.50  | 1– Fault  | 2.1777 | 2.1777 | 2.1777 |
|       |       |      |        | 2-3       | 0.3324 | 0.3324 | 0.3324 |
|       |       |      |        | 2-6       | 1.3832 | 1.3832 | 1.3832 |
|       |       |      |        | 3-4       | 2.1301 | 2.1301 | 2.1301 |
|       |       |      |        | Fault– 3  | 2.1949 | 2.1949 | 2.1949 |
|       |       |      |        | 4-5       | 0.1460 | 0.1460 | 0.1460 |
|       |       |      |        | 5-6       | 0.4538 | 0.4538 | 0.4538 |
| 2-3   | 4.752 | 1987 | -54.10 | 1-2       | 1.0914 | 1.0914 | 1.0914 |
| _     | 4.752 | 1987 | -174.1 | 1-3       | 0.3864 | 0.3864 | 0.3864 |
|       | 4.752 | 1987 | 65.90  | 2-3       | 0.0000 | 0.0000 | 0.0000 |
|       |       |      |        | 2-6       | 1.6376 | 1.6376 | 1.6376 |
|       |       |      |        | 2– Fault  | 2.4691 | 2.4691 | 2.4691 |
|       |       |      |        | 3-4       | 2.1782 | 2.1782 | 2.1782 |
|       |       |      |        | Fault-3   | 2.2882 | 2.2882 | 2.2882 |
|       |       |      |        | 4 – 5     | 0.0967 | 0.0967 | 0.0967 |
|       |       |      |        | 5-6       | 0.3421 | 0.3421 | 0.3421 |
| 2-6   | 5.332 | 2230 | -50.95 | 1-2       | 1.7123 | 1.7123 | 1.7123 |
|       | 5.332 | 2230 | -170.9 | 1-3       | 0.3989 | 0.3989 | 0.3989 |
|       | 5.332 | 2230 | 69.05  | 2-3       | 0.9587 | 0.9587 | 0.9587 |
|       |       |      |        | 2-6       | 0.0000 | 0.0000 | 0.0000 |
|       |       |      |        | 2– Fault  | 2.5862 | 2.5862 | 2.5862 |
|       |       |      |        | 3 - 4     | 1.4753 | 1.4753 | 1.4753 |
|       |       |      |        | 4 - 5     | 0.6090 | 0.6090 | 0.6090 |
|       |       |      |        | 5-6       | 0.5145 | 0.5145 | 0.5145 |
|       |       |      |        | Fault – 6 | 2.7718 | 2.7718 | 2.7718 |
| 3 – 4 | 5.359 | 224  | -51.3  | 1-2       | 0.6421 | 0.6421 | 0.6421 |
|       | 5.359 | 224  | -171   | 1-3       | 1.0053 | 1.0053 | 1.0053 |
|       | 5.359 | 224  | 68.6   | 2-3       | 1.2333 | 1.2333 | 1.2333 |
|       |       |      |        | 2-6       | 1.1004 | 1.1004 | 1.1004 |
|       |       |      |        | 3 - 4     | 0.0000 | 0.0000 | 0.0000 |
|       |       |      |        | 3– Fault  | 2.2172 | 2.2172 | 2.2172 |
|       |       |      |        | 4-5       | 0.6983 | 0.6983 | 0.6983 |
|       |       |      |        | Fault – 4 | 3.1603 | 3.1603 | 3.1603 |
|       |       |      |        | 5-6       | 0.8689 | 0.8689 | 0.8689 |
| 4 – 5 | 4.301 |      | -57.10 | 1-2       | 0.8594 | 0.8594 | 0.8594 |
|       | 4.301 |      | -177.1 | 1-3       | 0.5320 | 0.5320 | 0.5320 |
|       | 4.301 |      | 62.90  | 2-3       | 0.4501 | 0.4501 | 0.4501 |
|       |       |      |        | 2-6       | 0.3495 | 0.3495 | 0.3495 |
|       |       |      |        | 3-4       | 0.6130 | 0.6130 | 0.6130 |
|       |       |      |        | 4-5       | 0.0000 | 0.0000 | 0.0000 |

|     | 1 |  |           |        |        |        |
|-----|---|--|-----------|--------|--------|--------|
|     |   |  | 4 – Fault | 2.6544 | 2.6544 | 2.6544 |
|     |   |  | 5 - 6     | 1.7916 | 1.7916 | 1.7916 |
|     |   |  | Fault – 5 | 1.6433 | 1.6433 | 1.6433 |
| 5-6 |   |  | 1-2       | 1.2506 | 1.2506 | 1.2506 |
|     |   |  | 1-3       | 0.3023 | 0.3023 | 0.3023 |
|     |   |  | 2-3       | 0.4223 | 0.4223 | 0.4223 |
|     |   |  | 2-6       | 1.4547 | 1.4547 | 1.4547 |
|     |   |  | 3 - 4     | 0.6720 | 0.6720 | 0.6720 |
|     |   |  | 4 - 5     | 1.2740 | 1.2740 | 1.2740 |
|     |   |  | 5.6       | 0.0000 | 0.0000 | 0.0000 |
|     |   |  | 5 – Fault | 1.2309 | 1.2309 | 1.2309 |
|     |   |  | Fault – 6 | 3.5040 | 3.5040 | 3.5040 |

 TABLE VI

 BUS RESULTS DATA OF 6- BUS POWER SYSTEM MODEL

| DUS KESUL                        | IS DATA O | F O- BUS POW              | ER SYSTEM MO | DEL  |  |  |  |
|----------------------------------|-----------|---------------------------|--------------|--|--|--|--|
| Line Fault                       |           | Bus Voltages during Fault |              |  |  |  |  |
| (50 % location<br>between lines) | Bus       | Phase A                   | Phase B      | Phase C  |  |  |  |
|                                  | 1         | 0.0705                    | 0.0705       | 0.0705   |  |  |  |
| 1-2                              | 2         | 0.09339                   | 0.09339      | 0.09339  |  |  |  |
|                                  | 3         | 0.25367                   | 0.25367      | 0.25367  |  |  |  |
|                                  | 4         | 0.31028                   | 0.31028      | 0.31028  |  |  |  |
|                                  | 5         | 0.24158                   | 0.24158      | 0.24158  |  |  |  |
|                                  | 6         | 0.22385                   | 0.22385      | 0.22385  |  |  |  |
|                                  | Fault Pt  | 0.00000                   | 0.00000      | 0.00000  |  |  |  |
| 1-3                              | 1         | 0.27629                   | 0.27629      | 0.27629  |  |  |  |
|                                  | 2         | 0.33482                   | 0.33482      | 0.33482  |  |  |  |
|                                  | 3         | 0.27805                   | 0.27805      | Phase C           0.0705           0.09339           0.25367           0.31028           0.24158           0.22385           0.00000           0.27629           0.33482           0.27805           0.34519           0.37553           0.41077           0.00000           0.29662           0.23466           0.21727           0.28608           0.30153           0.32261 |  |  |  |
|                                  | 4         | 0.34519                   | 0.34519      | 0.34519  |  |  |  |
|                                  | 5         | 0.37353                   | 0.37353      | 0.37353  |  |  |  |
|                                  | 6         | 0.41077                   | 0.41077      | 0.41077  |  |  |  |
|                                  | Fault Pt  | 0.00000                   | 0.00000      | 0.00000  |  |  |  |
| 2 - 3                            | 1         | 0.29662                   | 0.29662      | 0.29662  |  |  |  |
|                                  | 2         | 0.23466                   | 0.23466      | 0.23466  |  |  |  |
|                                  | 3         | 0.21727                   | 0.21727      | 0.21727  |  |  |  |
|                                  | 4         | 0.28608                   | 0.28608      | 0.28608  |  |  |  |
|                                  | 5         | 0.30153                   | 0.30153      | 0.30153  |  |  |  |
|                                  | 6         | 0.32261                   | 0.32261      | 0.32261  |  |  |  |
|                                  | Fault Pt  | 0.00000                   | 0.00000      | 0.00000  |  |  |  |
| 2 - 6                            | 1         | 0.18966                   | 0.18966      | 0.18966  |  |  |  |
|                                  | 2         | 0.08184                   | 0.08184      | 0.08184  |  |  |  |
|                                  | 3         | 0.26081                   | 0.26081      | 0.26081  |  |  |  |
|                                  | 4         | 0.30738                   | 0.30738      | 0.30738  |  |  |  |
|                                  | 5         | 0.15231                   | 0.15231      | 0.15231  |  |  |  |
|                                  | 6         | 0.08467                   | 0.08467      | 0.08467  |  |  |  |
|                                  | Fault Pt  | 0.00000                   | 0.00000      | 0.00000  |  |  |  |
| 3 - 4                            | 1         | 0.29099                   | 0.29099      | 0.29099  |  |  |  |
|                                  | 2         | 0.27000                   | 0.27000      | 0.27000  |  |  |  |
|                                  | 3         | 0.03506                   | 0.03506      | 0.03506  |  |  |  |
|                                  | 4         | 0.04997                   | 0.04997      | 0.04997  |  |  |  |
|                                  |           |                           |              |  |  |  |  |

| 5        | 0.22626  | 0.22626   | 0.22626   |
|----------|--|---|---|
| 6        | 0.31652  | 0.31652   | 0.31652   |
| Fault Pt | 0.00000  | 0.00000   | 0.00000   |
| 1        | 0.47822  | 0.47822   | 0.47822   |
| 2        | 0.43886  | 0.43886   | 0.43886   |
| 3        | 0.35625  | 0.35625   | 0.35625   |
| 4        | 0.33677  | 0.33677   | 0.33677   |
| 5        | 0.20817  | 0.20817   | 0.20817   |
| 6        | 0.41604  | 0.41604   | 0.41604   |
| Fault Pt | 0.00000  | 0.00000   | 0.00000   |
| 1        | 0.38815  | 0.38815   | 0.38815   |
| 2        | 0.31356  | 0.31356   | 0.31356   |
| 3        | 0.38143  | 0.38143   | 0.38143   |
| 4        | 0.40252  | 0.40252   | 0.40252   |
| 5        | 0.07792  | 0.07792   | 0.07792   |
| 6        | 0.20895  | 0.20895   | 0.20895   |
| Fault Pt | 0.00000  | 0.00000   | 0.00000   |
|          | 6<br>Fault Pt<br>1<br>2<br>3<br>4<br>5<br>6<br>Fault Pt<br>1<br>2<br>3<br>3<br>4<br>5<br>6 | 6         0.31652           Fault Pt         0.00000           1         0.47822           2         0.43886           3         0.35625           4         0.33677           5         0.20817           6         0.41604           Fault Pt         0.00000           1         0.38815           2         0.31356           3         0.38143           4         0.40252           5         0.07792           6         0.20895 | 6         0.31652         0.31652           Fault Pt         0.00000         0.00000           1         0.47822         0.47822           2         0.43886         0.43886           3         0.35625         0.35625           4         0.33677         0.33677           5         0.20817         0.20817           6         0.41604         0.41604           Fault Pt         0.00000         0.00000           1         0.38815         0.38815           2         0.31356         0.31356           3         0.38143         0.38143           4         0.40252         0.40252           5         0.07792         0.07792           6         0.20895         0.20895 |

## III. CONCLUSION

This paper described symmetrical fault or three phase balanced fault analysis of 6-bus power system model using software tool, PowerWorld Simulator. The simulator tool greatly enhances the electrical engineering student's ability and utility engineers to visualize fault current distribution and bus voltage levels during fault conditions in order to give information for the selection and coordination of protective equipment to ensure the safe and reliable operation of the system. This fault analysis was created using the student version of PowerWorld simulator that is limited to 13 buses. The full version is relatively inexpensive and provides the user capability to model much larger and complex power system networks.

#### REFERENCES

- P.Kundur, Power System Stability and Control, First Edition, McGraw-Hill, Inc., New York, 1994
- [2] J. Duncan Glover, S. Sarma Mulukutla, Thomas J.Overbye, Power System Analysis and Design, Fifth Edition, Cengage Learning, USA, 2011
- [3] Technical Software, Power World simulator ver. 20 Education/Evaluation, www.powerworld.com/download
- [4] EE433 LAB Appendix, Case Study Using PowerWorld Simulator
- [5] P. M. Anderson and A. A. Fouad, Power System Control and Stability, Second Edition, IEEE Press, 2003
- [6] J Rohan Lucas, EE 423-Power System Analysis & Power System Faults, section 2

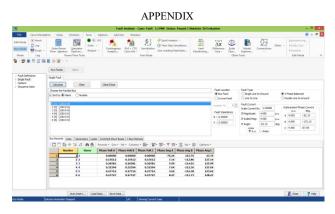


Fig. 1(a) Bus voltage records at bus 1

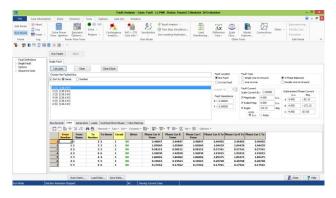


Fig. 1(b) Branch current records at bus 1

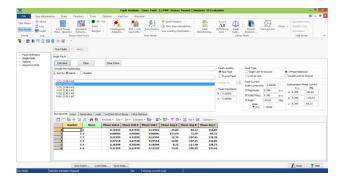


Fig. 2(a) Bus voltage records at bus 2

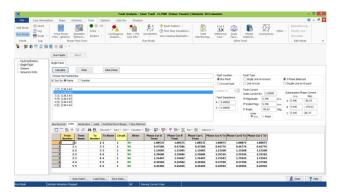


Fig. 2(b) Branch current records at bus 2

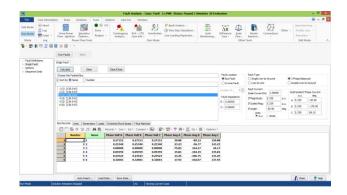


Fig. 3(a) Bus voltage records at bus 3

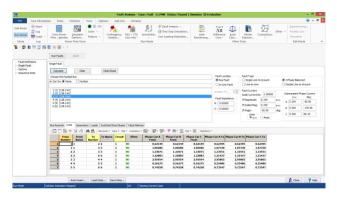


Fig. 3(b) Branch current records at bus 3

| 8                                 |   | Fault Analysis - Ca                                | se: Fault 11.PWB Status   | Paused   Simulator 25                  | Evaluation                                 |                   | - 0 - 1   |  |  |  |  |  |
|-----------------------------------|---|--|---|--|--|-------------------|---|--|--|--|--|--|
| File Case Informa                 | tion Draw Orelines Tools  | Options Add Ons Window                             |   |  |  |                   | <del>0</del> - 0  |  |  |  |  |  |
| Mode Log                          | Sche Power Smulater<br>Plow - Liewfon Optione<br>Power Plow Tools | re - Contingency RAS - CTG<br>Analysis Case Info - | T V fault Analy<br>T V (3) Time Step 5<br>Sensitivities<br>Line Loading R | inulation                              |  | Medel<br>Explore. | 20her - Exclusionengu<br>Modily Case -<br>Resumber -<br>Edit Mode |  |  |  |  |  |
| ·罗西田耳霸                            | 🖩 🛞 🔐 - +   |  |   |  |  |                   |   |  |  |  |  |  |
|                                   | Run Faults Abort  |  |   |  |  |                   |   |  |  |  |  |  |
| Fault Definitions<br>Single Fault | Single Paul   |  |   |  |  |                   |   |  |  |  |  |  |
| Options<br>Securice Data          | Calculate Clear   | Clear/Close  |   |  |  |                   |   |  |  |  |  |  |
| 1000000000                        | Choose the Faulted Bus  |  | Fault Location  | FaultType                              |  |                   |   |  |  |  |  |  |
|                                   | Sort by Inane O Number  |  | ● Bus Fault<br>○ this reak  | Gingle Line-to-Ground     Line-to-Line | 3 Phase Balanced     Oouble Line-to-Ground |                   |   |  |  |  |  |  |
|                                   | 1 (1) [138.0 kV]<br>2 (2) [138.0 kV]<br>3 (2) [138.0 kV]          |  | Location % 0  | Scale Current By: 1.00003              | Subtransient Phase Current                 |                   |   |  |  |  |  |  |
|                                   | 5 (2) [128.04v]   |  | Fault Inpedance<br>R : 0.00000  |  | A 5.407 -51.58                             |                   |   |  |  |  |  |  |
|                                   | 6 (8) [138.0 kV]  |  | X 0.00000   | If Scaled Nagi 5.407                   | p.u. g 5.407 -171.58                       |                   |   |  |  |  |  |  |
|                                   |   |  | A 1 930000  | If Angle: -51.58                       | deg.<br>c 5.407 68.42                      |                   |   |  |  |  |  |  |
|                                   |   |  |   |  |  | I DIU. O Amps     | 6 2.407 Dark  |  |  |  |  |  |
|                                   | Bus Records Lines Generators Lo                                   | ads   Switched Shunt Buses   Y-Bus Matric          | es.   |  |  |                   |   |  |  |  |  |  |
|                                   |   | Records * Geo * Set * Columno *                    |   | - W mi - EE   Onto                     | and Y                                      |                   |   |  |  |  |  |  |
|                                   | Humber Name   | Phase Volt A Phase Volt 8 Pt                       | ase Volt C Phase Ang A  | Phase Ang B Phase                      | ling C                                     |                   |   |  |  |  |  |  |
|                                   | 1 11  | 0.30594 0.30594                                    | 0.30594 30.69   |  | 50.69                                      |                   |   |  |  |  |  |  |
|                                   | 2 22  | 0.28208 0.28208                                    | 0.28208 23.93   |  | 43.83                                      |                   |   |  |  |  |  |  |
|                                   | 3 33  | 0.05454 0.05464 0.00000                            | 0.06464 25.35<br>0.00000 -116.46  | -94.65                                 | 45.35                                      |                   |   |  |  |  |  |  |
|                                   | 3 33  | 0.21259 0.21259                                    | 0.21250 14.42   |  | 34.42                                      |                   |   |  |  |  |  |  |
|                                   | 6   | 0.33691 0.33691                                    | 0.33691 18.85   | -101.15                                | 38.85                                      |                   |   |  |  |  |  |  |
|                                   | Auto Dovert   | od Dela Save Data                                  |   |  |  |                   | Close ? Heb   |  |  |  |  |  |
|                                   |   |  |   |  |  |                   |   |  |  |  |  |  |

Fig. 4(a) Bus voltage records at bus 4

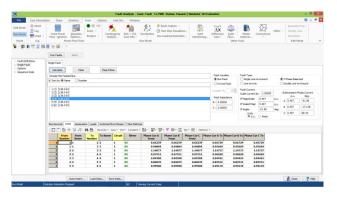


Fig. 4(b) Branch current records at bus 4

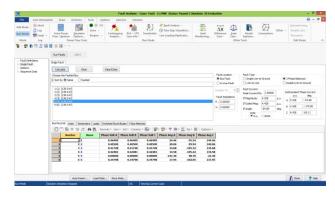


Fig. 5(a) Bus voltage records at bus 5

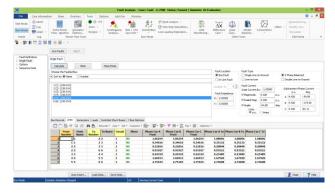


Fig. 5(b) Branch current records at bus 5

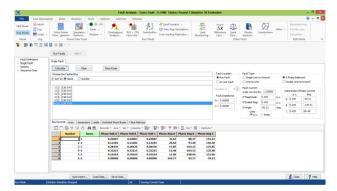


Fig. 6(a) Bus voltage records at bus 6

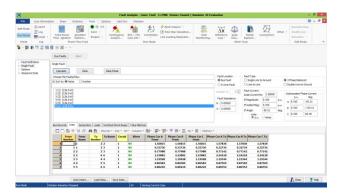


Fig. 6(b) Branch current records at bus 6

www.rsisinternational.org

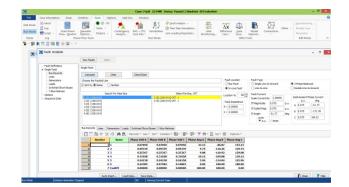


Fig. 7(a) Bus voltage records at line1-2

| File         | Case Information Draw  | Onelines Taolis Options Add Ons Windo   |   |                                      |                                |   |  |  |  |
|--------------|--|---|---|--------------------------------------|--------------------------------|---|--|--|--|
| Mode<br>Mode | ⊗Abort<br>Steg<br>Solpt - Firm - Steven<br>Log Pereton   | Sime -<br>Spectator<br>Optionen.<br>Retjore -<br>Retjore -<br>Analysis<br>Retjore - | de T     de T     de T     de Tarres Dep Sexulation.     Sexulation.     Line Looding Replicator.     Monitoring. | Difference<br>Case - Case - Other To | Medel Connections Other        | Equivalencing<br>Modify Case 1<br>Resumber 1<br>Edit Mode |  |  |  |
| 1004         |  | wer How 1005  | Pun Mode  | Uther is                             | 645                            | FBEWODE   |  |  |  |
| - 35 1       | 1日間部間の第一・  |   |   |                                      |                                |   |  |  |  |
|              | Fault Analysis   |   |   |                                      |                                |   |  |  |  |
|              |  | Run Paulta Abort  |   |                                      |                                |   |  |  |  |
|              | - Fault Definitions  | Single Fault  |   |                                      |                                |   |  |  |  |
|              | Dua Records  | Calculate Obar Obar Obar  |   |                                      |                                |   |  |  |  |
|              | - Canarators<br>- Landa<br>- Seitched Shunt Buses<br>> Y Bus Natrices<br>- Option<br>> Sequence Data | Choose the Faulted Line   |   | Pault Location                       | Sinde Line to-Ground           | 10 and Edward   |  |  |  |
|              |  | Sortby INane O Number   |   | 10 In Street Fault                   | Outre-to-time Obuble Une-to-Gr |   |  |  |  |
|              |  | Search For Islam Bus  | falent Far Bus. Off   | Location % SO[5]                     |                                |   |  |  |  |
|              |  | 11(0 (138.0k/)  | 2 (0) [138.0 W] OKT 1   |                                      | Scale Current By: 1.00000      | Subtransient Phase Current                                |  |  |  |
|              |  | 2 (2) [138.04/0]<br>3 (2) [138.04/0   | 3 (0) [138.0 W] OKT 1   | Fault Impedance<br>R : 0.00000       | of Magnitude: 5.075 p          | A 5.075 -51.77  |  |  |  |
|              |  | 4 (4) [138.0 kV]<br>5 (5) [138.0 kV]  |   |                                      | of Scaled Mag: \$.075 p.u.     |   |  |  |  |
|              |  | 6 (6) [138.0 kV]  |   | X : 0.00000                          | tif Angle: -51.77 deg          |   |  |  |  |
|              |  |   |   |                                      | With O Amps                    | c 5.075 68.23   |  |  |  |
|              |  | But Becards 1945 Generators Loads Switched Stu                                      | these Ville Meline  |                                      |                                |   |  |  |  |
|              |  | 100 5h 4h 1d /5 4h 4h Bernets - Ge  | • Set - Columni - 阳· 雷· 雷· 平田· 田川   | b) • III Options •                   |                                |   |  |  |  |
|              |  | I too I too Its heated to heat I three  | Ban Gr &   Ban Gr &   Ban Gr C  Ban Gr & To  Ban  |                                      |                                |   |  |  |  |
|              |  | Rother Rent 1 2 2 1 ND  | Prim         Prim           3.0000         0.0000         0.0000  | 6.80000 C.30000                      |                                |   |  |  |  |
|              |  | 2 11 22 1 NO  | 6.75850 6.75850 0.75850 0.75854<br>3.22795 3.22795 3.22995  | 6.75054 6.75054<br>1.20830 1.20835   |                                |   |  |  |  |
|              |  | 4 22 22 2 20  | Addie Addie CANNA CANNA   | 5.87950 5.87950<br>3.51870 3.11870   |                                |   |  |  |  |
|              |  | 5 7 Faulth 2.2 5 NO   | 2.12585 2.12585 2.15585 2.1858<br>2.85286 2.85386 2.85286 2.85873   | 3.89079 3.89879                      |                                |   |  |  |  |
|              |  |   | 5,29580 5,29580 5,29580 5,29520<br>5,29520 5,29520 5,29520 5,29520  | L29472 L29472<br>L28781 628781       |                                |   |  |  |  |
|              |  | <b>1</b> 13 14 1 <b>1</b>   | 6.18171 6.18171 0.18171 0.18176   | 6.18746 6.18746                      |                                |   |  |  |  |
|              |  |   |   |                                      |                                | Core 7 Helo   |  |  |  |

Fig. 7(b) Branch current records at line 1-2

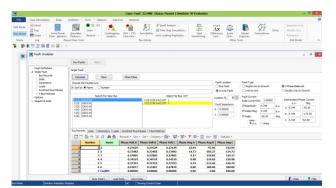


Fig. 8(a) Bus voltage records at line1-3

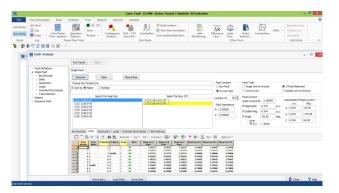


Fig. 8(b) Branch current records at line 1-3

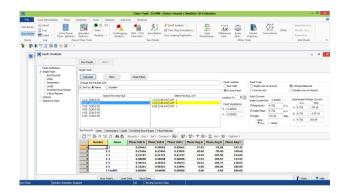


Fig. 9(a) Bus voltage records at line 2-3

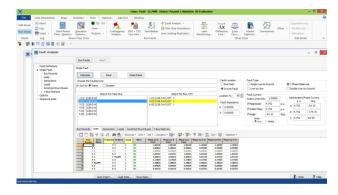


Fig. 9(b) Branch current records at line 2-3

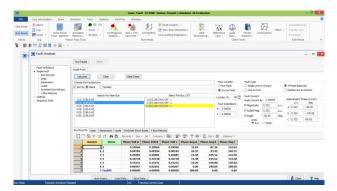


Fig. 10(a) Bus voltage records at line 2-6

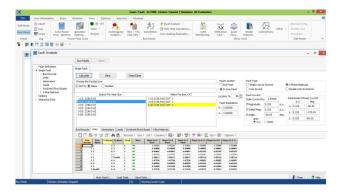


Fig. 10(b) Branch current records at line 2-6

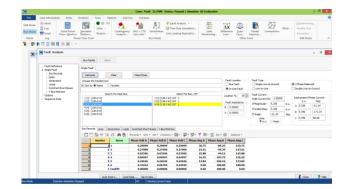


Fig. 11(a) Bus voltage records at line 3-4

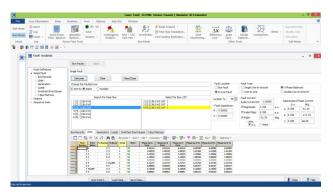


Fig. 11(b) Branch current records at line 3-4

| _                    |   |   |                     | Case: Pac       | alt 22.PWB Sta   | ALL: MALECO [ 1  | andator 20 Ca | allastion      |  |   |              |                                      | - 6                                     |  |
|----------------------|---|---|---------------------|-----------------|------------------|--|---------------|----------------|--|---|--------------|--------------------------------------|---|--|
| •                    | Case Information Draw   | Onelines Tools  | Options Add         | Ons Window      | w                |  |               |                |  |   |              |                                      |   |  |
| ilode<br>Mode<br>ide |   | Sireulator<br>Optione<br>wer Row Tools  |                     | Case info -     | TA C             | Eault Analysis<br>Time Step Sieu<br>ne Loading Repli               | lation-       | Linit Dr       | terror<br>and Scale<br>and Cane.                                   | Model Con<br>Explorer.  | Sections of  | Beer + Equivale<br>Renumb<br>Edit to | ase +<br>er -                           |  |
| S 1                  | 日間になる。  |   |                     |                 |                  |  |               |                |  |   |              |                                      |   |  |
| 10                   | Fault Analysis  |   |                     |                 |                  |  |               |                |  |   |              |                                      |   |  |
| -                    |   | Run Faults  | Abort               |                 |                  |  |               |                |  |   |              |                                      |   |  |
|                      | - Pault Definitions<br>4 Sindle Fault   | Single Fault  |                     |                 |                  |  |               |                |  |   |              |                                      |   |  |
|                      | - But Recards     - But Recards     - Unrel     - Correntum     - Contractum     - Contractum     - Secure Case     - Your Motions     - Option     - Sequence Case | Cakulate  | Cear                | Gear/Gase       |                  |  |               |                |  |   |              |                                      |   |  |
|                      |   |   |                     |                 |                  |  |               | Fault Location | FaultType  |   |              |                                      |   |  |
|                      |   | Sortby Name O Number  |                     |                 |                  |  |               |                | Dus Fault  | Single Line to-Ground     Souther Line to-Ground     Double Line to-Ground  |              |                                      |   |  |
|                      |   |   | Search For Near Bus |                 |                  | Salect Far   | But OT        |                |  |   |              |                                      |   |  |
|                      |   | 1 (0) [138.04V]<br>2 (2) [138.04V]  |                     |                 | 3 (3) [138.0     | 3 (3) [38.0 W] OCT 1<br>5 (3) [38.0 W] OCT 1<br>Pault 1<br>R : 0.0 |               |                | Locaton % 50 (\$)<br>Pault Impedance<br>R : 0.00000<br>X : 0.00000 | Scale Current By:         1.000           2f Magnitude:         4.301           3f Scaled Mag:         4.301           3f Angle:         -57.10 | 1.00000      |                                      | Subtransient Phase Current<br>p.u. dep. |  |
|                      |   | 2 (G) (138.044)<br>3 (G) (138.044)<br>5 (G) (138.044)<br>5 (G) (138.044)<br>5 (6) (138.044) |                     | 1.9 (b) (1.00.0 | 4.301 p.u        |  |               |                |  |   | p.u. A 5301  | -57.10                               |   |  |
|                      |   |   |                     | -               | 4.301            |  |               |                |  |   | p.u. # 4.201 | -177.10                              |   |  |
|                      |   |   |                     |                 | -57.10           |  |               |                |  |   | deg. c 4.301 | 62.90                                |   |  |
|                      |   |   |                     |                 |                  |  |               |                |  | 0.055<br>(# p.u.  | Anes         | C [4.301                             | 62.90                                   |  |
|                      |   | Bue Records Lines   | Generators Load     | s Seithed Shun  | t Duses Y-Dus Ma | drices   |               |                |  |   |              |                                      |   |  |
|                      |   |   | 28 .28 44 45.       | Records * Geo   | • Set • Colum    | ······································                             | ·             | · III no - 1   | Options -  |   |              |                                      |   |  |
|                      |   | Bumbe   | r Name              | Phase Volt A    | Phase Volt 8     | Phase Volt C   | Phase Ang A   | Phase Ang B    | Phase Ang C  |   |              |                                      |   |  |
|                      |   | 1   | 11                  | 0.47822         |                  | 0.47822  | 24.01         | -95.91         |  |   |              |                                      |   |  |
|                      |   | 2   | 22                  | 0.43886         |                  | 0.43886  | 19.25         | -100.75        |  |   |              |                                      |   |  |
|                      |   |   | 4.4                 | 0.33675         |                  | 0.33677  | 15,40         | 104.7          |  |   |              |                                      |   |  |
|                      |   | 5   | 5.5                 | 0.20817         | 0.20817          | 0.20817  | 13.07         | -106.92        | 1 133.07   |   |              |                                      |   |  |
|                      |   | 6   | 66                  | 0.41604         |                  | 0.31426  | 0.00          | 180.00         |  |   |              |                                      |   |  |
|                      |   |   | 7 FoulsPt           |                 |                  |  |               |                |  |   |              |                                      |   |  |

Fig. 12(a) Bus voltage records at line 4-5

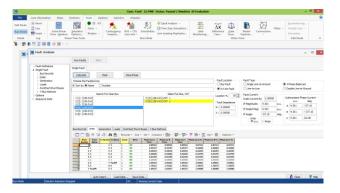


Fig. 12(b) Branch current records at line 4-5

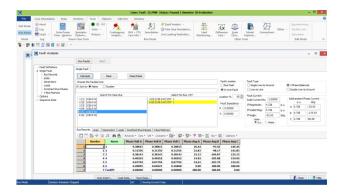


Fig. 13(a) Bus voltage records at line 5-6

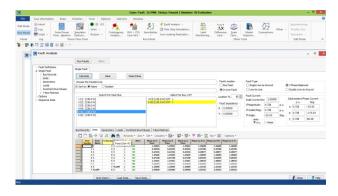


Fig. 13(b) Branch current records at line 5-6

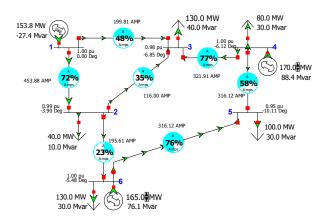


Fig. 14 Load flow analysis under steady state condition