Title : Renewable Energy Integration of 37-Bus System Using OpenModelica and OpenIPSL

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Abstract :

Renewable Energy Integration of 37 Bus System is implemented in OpenModelica by Using OpenIPSL library shown in figure 1. This 37 Bus Test Case is taken from the text book 'Power System Analysis and Design' by J. Duncan Glover and Mulukutla S. Sarma · It is constructed with three different voltage levels (69 kV, 138 kV and 345 kV), and all units entered in this modeling, are in per unit. This model consists 9 generators, 14 transformers, 24 loads and 43 power lines in case 1. In case 2, generator of bus no 30 replaced with PV and in case 3, generator of bus no 26 also replaced with type 3 wind turbine generator. A three phase balanced fault is simulated at bus no 17 for the duration of 0.6 seconds (3.5 seconds to 4.1 seconds). The purpose of this power system is to fault analysis and the voltage stability at multiple buses.
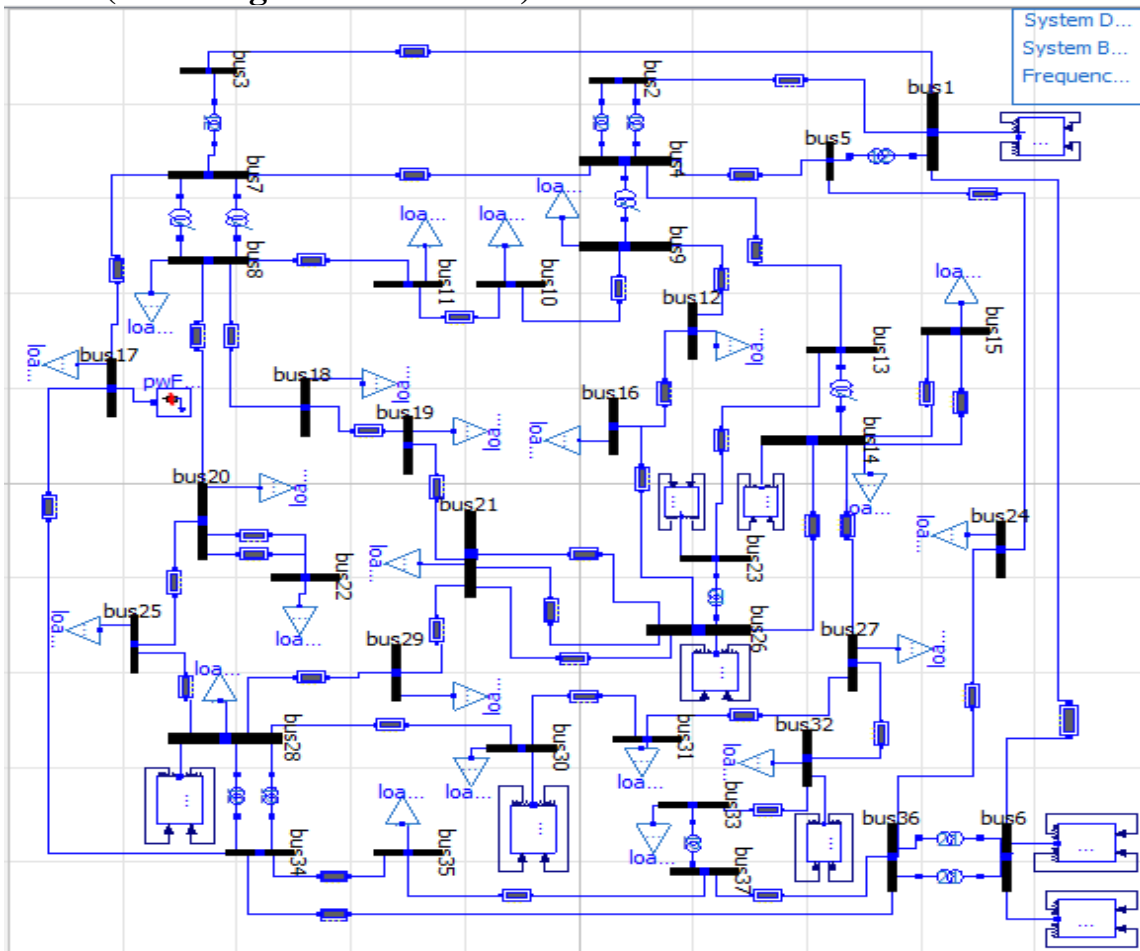
Case-1. (Modeling with GENROU) :

Figure 1 : Case 1. Connection of Glover 37-Bus System Using OpenIPSL

In case 1 GENROU connected at all generator buses. Renewable energy resources are not used in this case. This case is only for verifying the result when 37 bus system connected with GENROU.

Case 2. (Modeling with GENROU and PV) :

In this model both GENROU and PV are connected at generator bus. This is renewable energy integration by using solar system. Slack bus connected with generator but bus no 30 generator replaced with constant PV model. This modeling is only for checking response of buses voltage when system connected with solar.
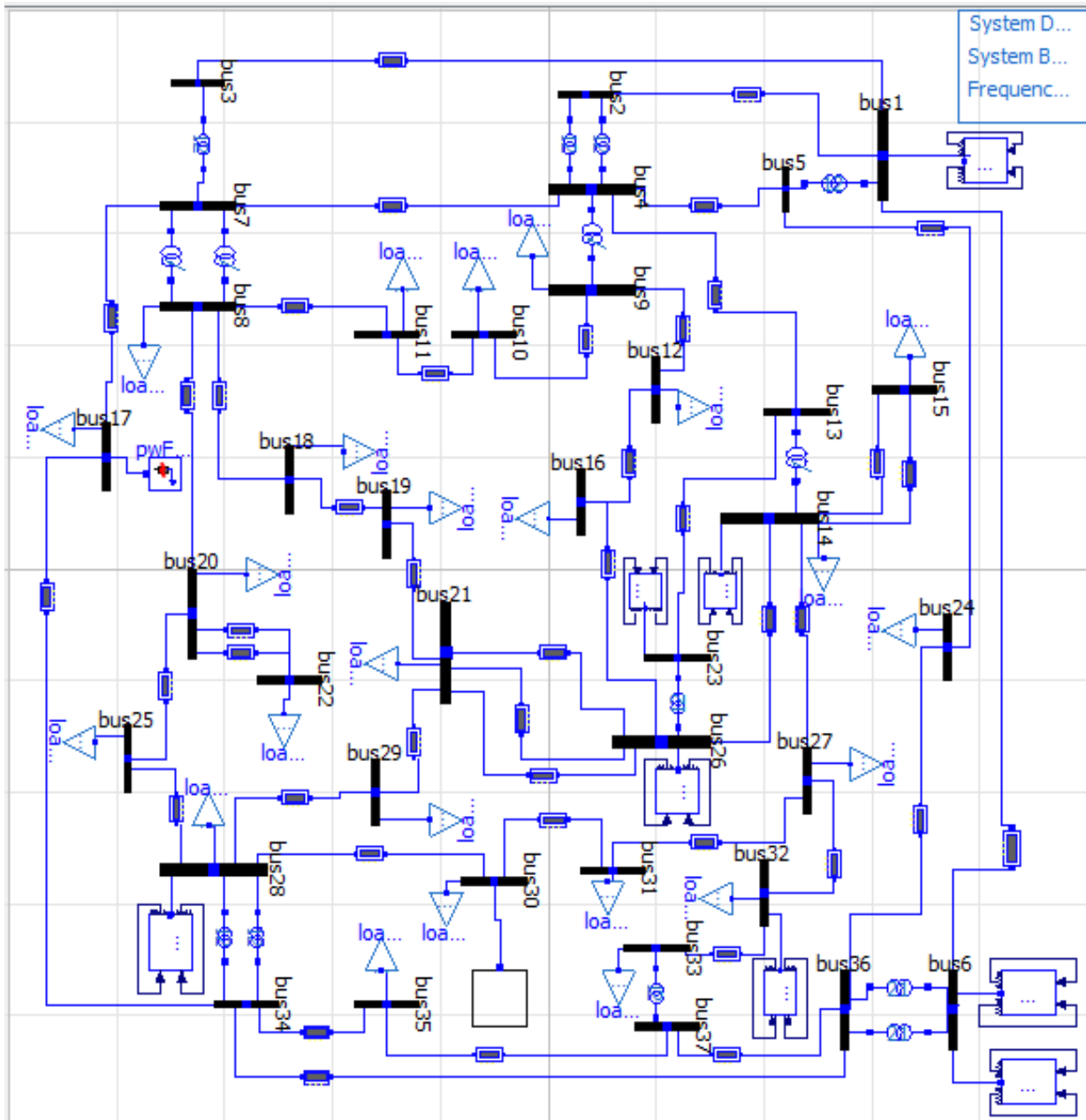

Figure 2 : Case 2. Solar Connected 37 Bus System Using OpenIPSL

Case 3. (Modeling With GENROU, PV and WT3G) :

In this case 37 bus system is modeled for renewable energy integration. A GENROU (genrou 7) is connected with slack bus (bus no 1) which operates at 345KV, (genrou 1) and (genrou 2) is connected with bus no 6 at 345KV, (genrou 3) is connected with bus no 32 at 69KV, (genrou 4) is connected with bus no 28 at 69KV, (genrou 5) is connected with bus no 14 at 69KV and (genrou 6) is connected with bus no 23 at 138KV. For renewable energy a constant PV is connected with bus no 30 at 69 KV and a wind turbine generator has connected with bus no 26 at 69 KV.
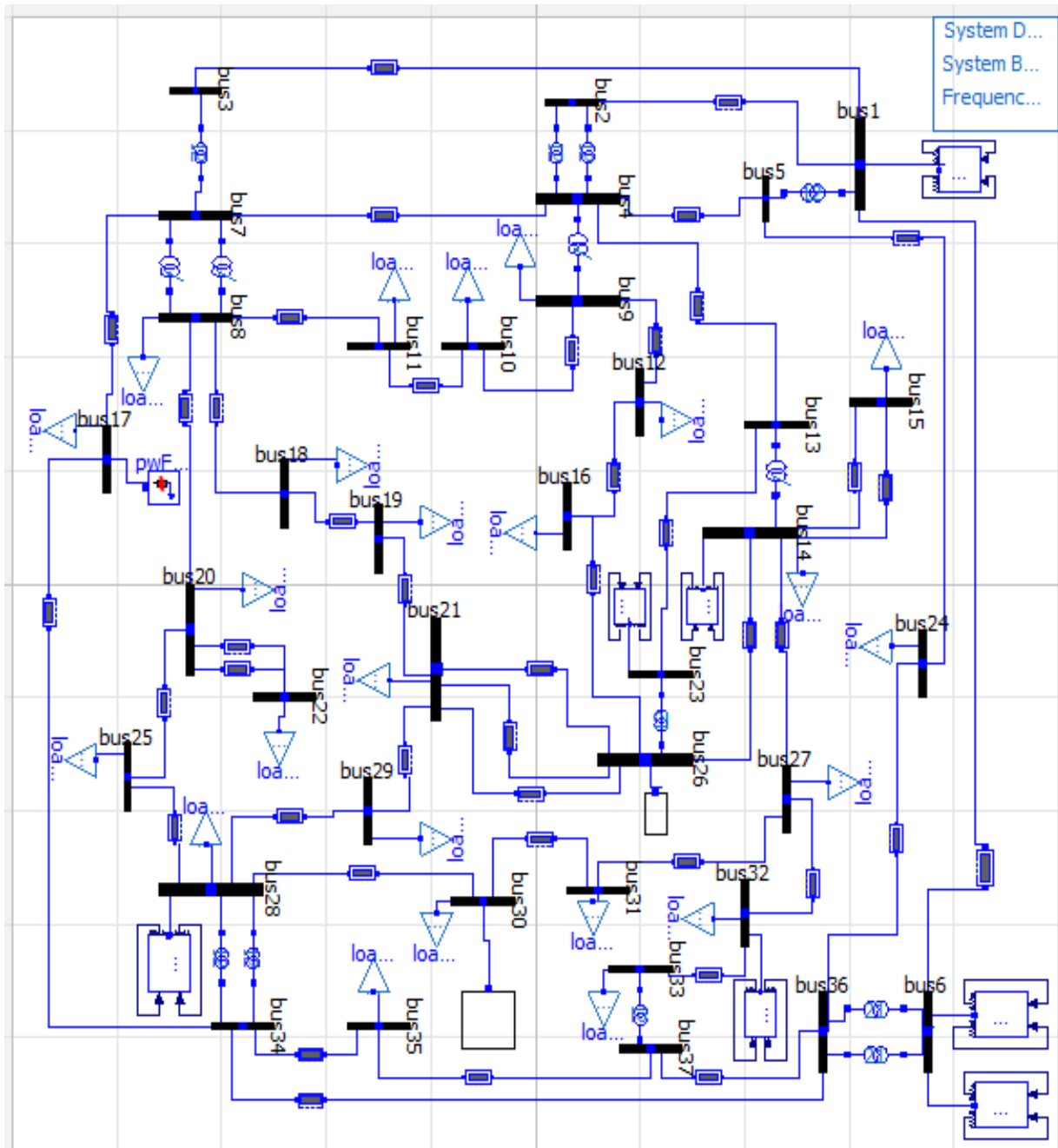

Figure 3 : Case 3. Glover 37-Bus System Integrated with PV and WT3G Using OpenIPSL
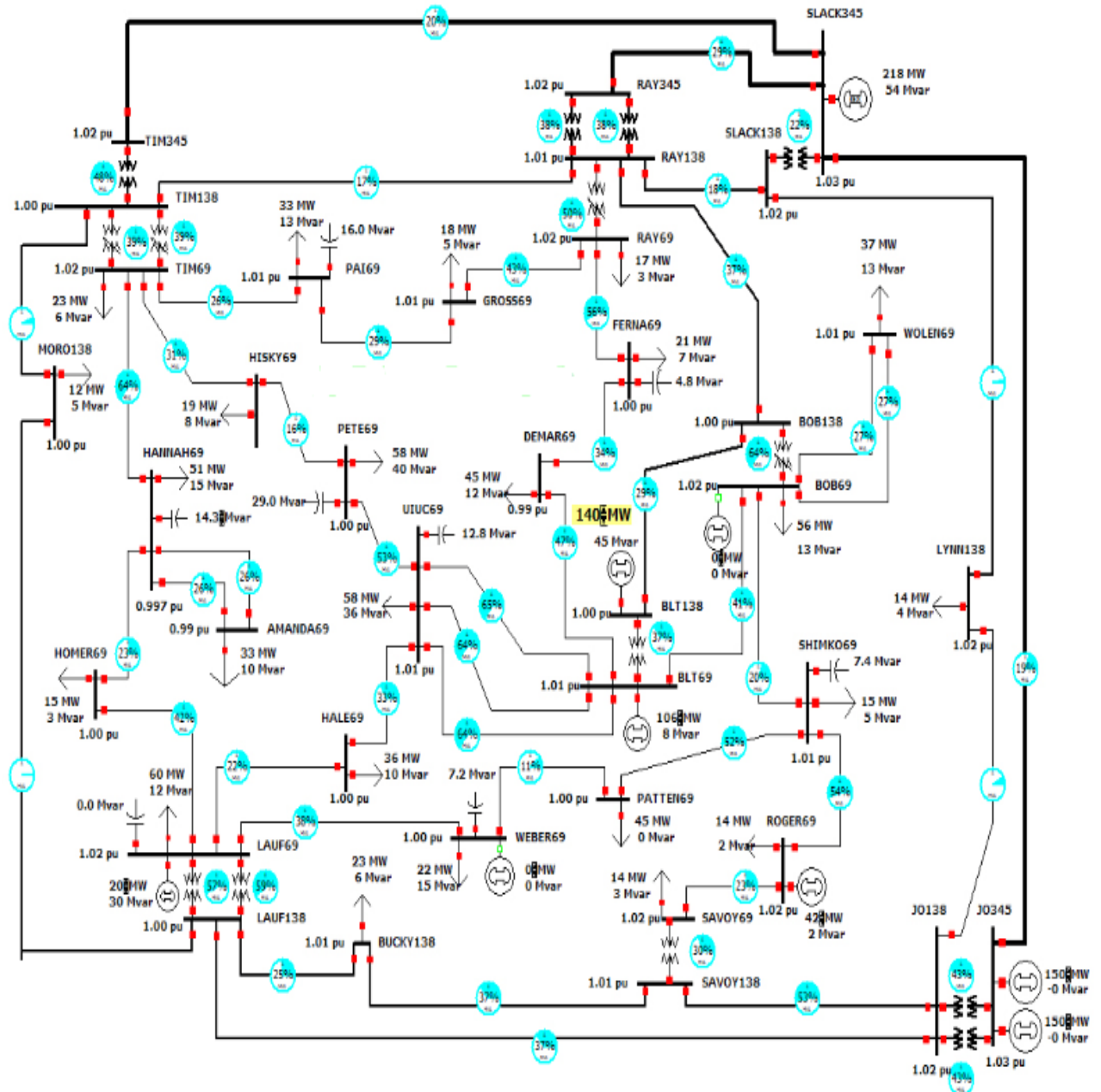
Single Line Diagram of 37 Bus System :

Figure 4 : Single Line Diagram of 37 Bus System

Explanation :

This Model Uses Following components –

Component Name	Class Path	Quantity
Bus	OpenIPSL.Electrical.Buses.Bus	37
Transmission Line	OpenIPSL.Electrical.Branches.PwLine	43
Load	OpenIPSL.Electrical.Loads.PSAT.LoadPQ	24
Generator	OpenIPSL.Electrical.Machines.PSSE.GENROU	Case 1.- 9 Case 2.- 8 Case 3.- 7
Wind Turbine Generator	OpenIPSL.Electrical.Wind.PSSE.WT3G.WT3G1	1
Transformer	OpenIPSL.Electrical.Branches.PSAT.Two Winding Transformer	10
Transformer	OpenIPSL.Electrical.Branches.PSAT.Two Winding Transformer Fixed Tap Ratio	4
Three Phase Fault	OpenIPSL.Electrical.Events.PWFault	1
Solar	OpenIPSL.Electrical.Solar.PSAT.ConstantPQPV.PQ1	1
System	OpenIPSL.Electrical.System Base	1

Result :

Case 1. :

In this case when simulation reached at 3.5 second suddenly buses voltage dips due to fault and when fault is cleared after 4.1 second voltage recovers after some oscillation. Voltage of bus no 17 has more dip because fault applied on 17th bus. Figure 5 shows the voltage profile of all 37 buses before and after the applying the fault. Single line model shown in Figure 1. This implementation is only for verifying the result and load flow solution of 37 bus system and the further cases shows the renewable energy integration.
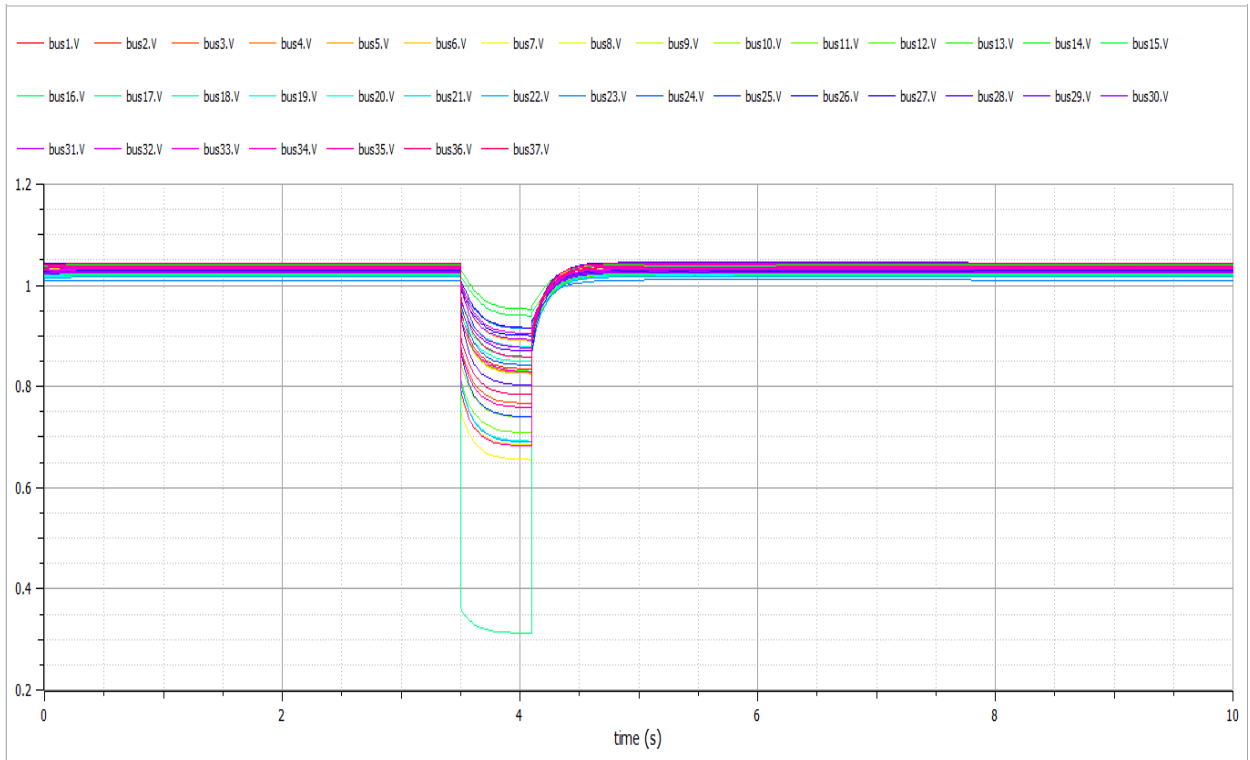
Figure 5 : All 37 buses voltage Profile Under Fault (Case 1)
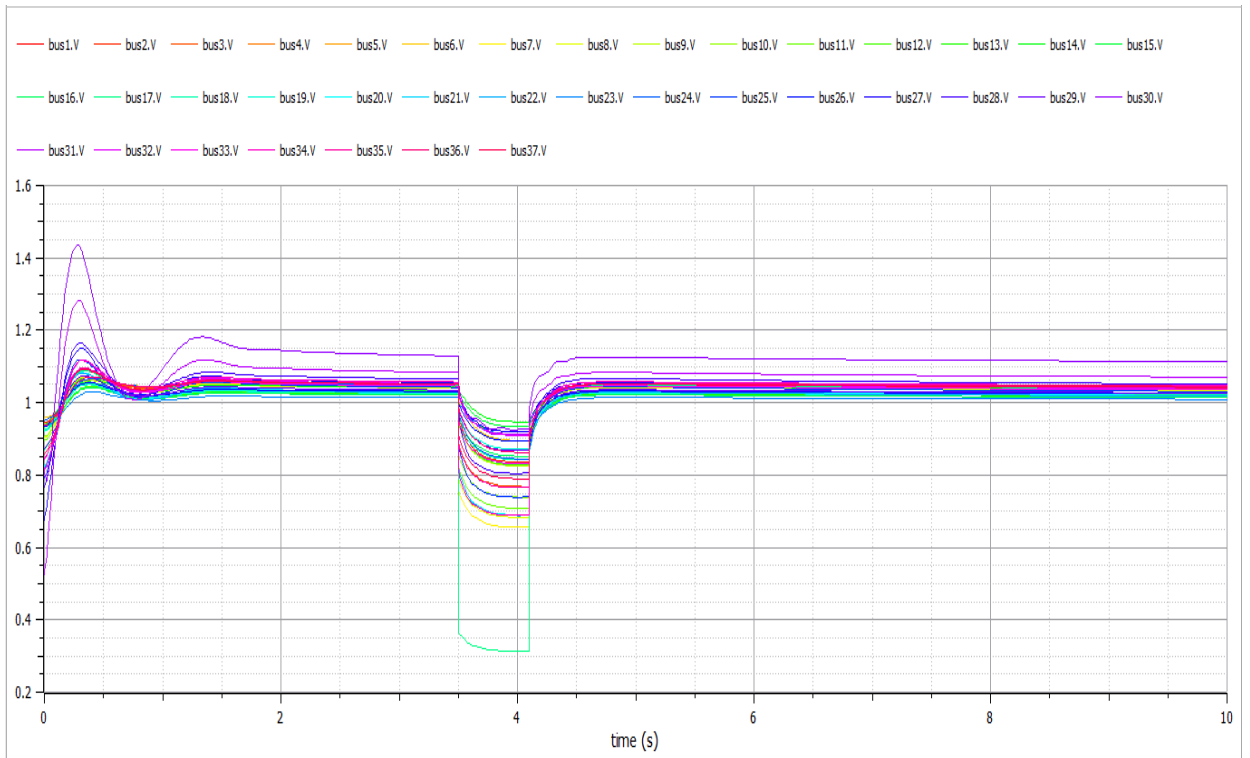
Case 2. :

Figure 6 : All 37 buses voltage Profile Under Fault (Case 2)

Figure 6 shows that the voltage response of all 37 buses in case 2. In this case a solar module is used at the place of bus no 30 generator. In this simulation result initial oscillation is due to invertor which uses in solar module. Because we know that invertor does not provide required reactive power to the grid. Hence initial oscillation is due to lack of reactive power in grid at the time of starting simulation.

Case 3. :

In this case a wind turbine generator is also used with solar and generator. Model of this case shown in Figure 3 and simulation result shown in Figure 7.

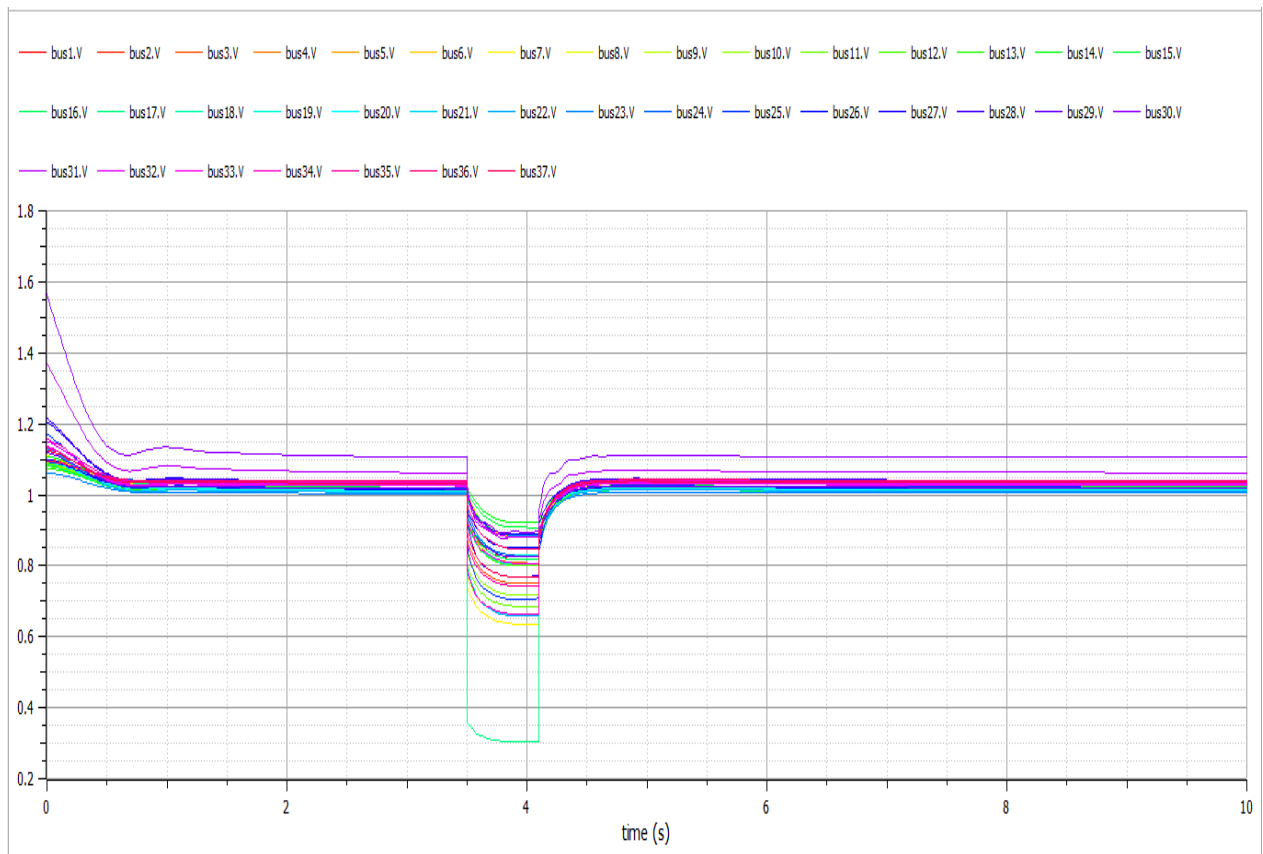Figure 7 : All 37 buses voltage Profile Under Fault (Case 3)

Bus Voltage Magnitude after Simulation

Bus No	Voltage Magnitude (pu)
1	1.04072
2	1.03712
3	1.03802
4	1.03331
5	1.04072

6	1.03957
7	1.03111
8	1.02745
9	1.03235
10	1.01653
11	1.01390
12	1.01330
13	1.01437
14	1.03407
15	1.02211
16	1.00957
17	1.03263
18	1.01643
19	1.01409
20	1.01049
21	1.01817
22	1.00919
23	1.00465
24	1.04072
25	1.02014
26	1.01817
27	1.03997
28	1.03955
29	1.01942
30	1.10630
31	1.06210
32	1.03028
33	1.02718
34	1.03781
35	1.03434
36	1.04023
37	1.03434

Table 1 : Bus Voltage Magnitude After Simulation

Conclusion :

The modeling of 37-bus model in OpenModelica is basically renewable energy integration. It represents the system behavior before and after the fault occurs at 17th Bus. WTG and PV voltage profile, active power and reactive power response mentioned in result. Some irrelevant behavior of reactive power of WTG and PV is due to using inverter in grid connected PV module because inverter cannot produce required reactive power. The voltage of all buses recovers after the fault clearing. The voltage profile of the buses indicates that the system can be brought back to stable operating condition even faster by adding additional controls such as power system stabilizer (PSS) and automatic voltage regulator (AVR).