Title: Five bus system under fault, AVR disturbances and line openings.

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Abstract:

The Five bus system is powered by two generators of order IV which are connected to bus1 and bus5. The generators are connected to Automatic Voltage Regulators (AVR). The two step-up transformers out of which one steps up the voltage level from 18Kv to 230Kv and other one step up from 13.8Kv to 230Kv

The system is subjected to below three conditions at given particular times.

1. Introducing disturbances in field voltage by changing the reference voltage in AVR.
2. Balanced three-phase ground fault starting from 5 secs for a duration of 0.1 secs
3. Opening and reclosing of power line between bus2 and bus3, i.e. pwline2_3, starting from 20 secs and for a duration of 5 secs.

The outputs under the two cases have been observed and explained.

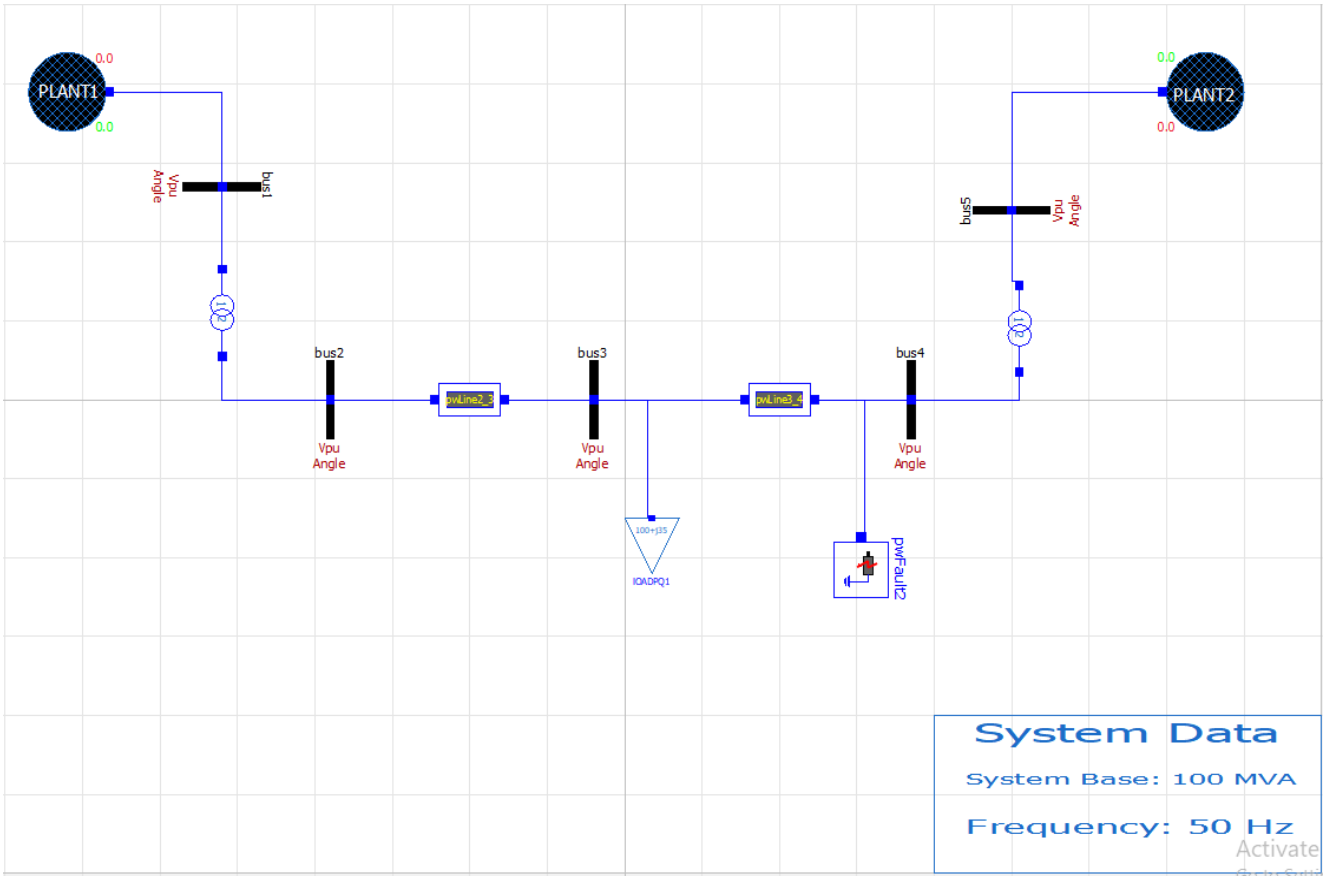

Figure 1: Modelling of Five bus system under fault, AVR disturbances and line openings.

Note: Kindly include all the models present in the zip file along with the OpenIPSL provided. It avoids any compatibility issues if any.

Explanation:

This model uses the following components

Component Name	Path	Number
Automatic Voltage Regulator (AVR)	OpenIPSL.Electrical.Controls.PSAT.AVR.AVRTypeII	2
Two Winding Transformer	OpenIPSL.Electrical.Branches.PSAT.TwoWindingTransformer	2
Boolean Constant block	Modelica.Blocks.Sources.BooleanConstant	2
Switch	Modelica.Blocks.Logical.Switch	2
Three phase fault	OpenIPSL.Electrical.Events.PwFault	1
PQ Load	OpenIPSL.Electrical.Loads.PSAT.VoltDependant	1
Step	Modelica.Blocks.Sources.Step	2
Generator (Order IV)	OpenIPSL.Electrical.Machines.PSAT.Order6	2
Bus	OpenIPSL.Electrical.Buses.Bus	5
PwLine	OpenIPSL.Electrical.Branches.PwLine	2
Sysdata block	OpenIPSL.Electrical.SystemBase	1

Case 1: *Introducing disturbances in field voltage by changing reference voltage in AVR.(refer to five_bus_system)*

In this model, the plant 1 and 2 are modelled along with AVR such that a disturbance can be inducted into the field voltage of the generator (refer to figure2). The reference voltage is changed by sending a step signal which has an offset value of the reference voltage signal and the height of step as given by the user. This results in an increase in terminal voltage of the generator which can be observed from the voltage profiles plotted shown in the figure3. The AVR disturbances are induced into plant 1. The step signal is induced at 12 secs and in the voltage profile we can observe the bus voltages start to increase after 12 secs and settle after some time at their final value. Here we can also observe that the voltage profile of Bus 5 (the other generator bus) is not affected by the AVR disturbance in Plant 1. This is because it is already connected to AVR which maintains its terminal voltage.

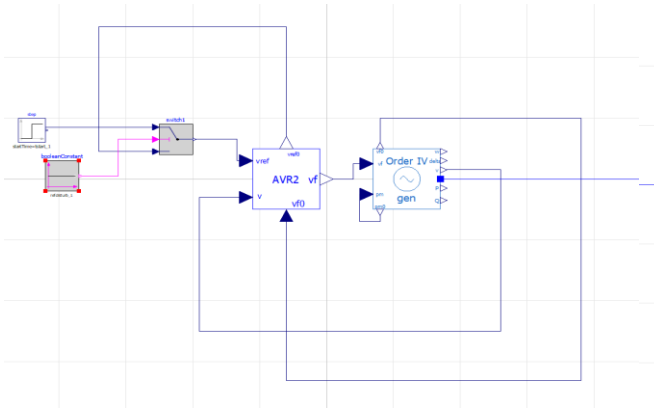

Figure 2: AVR and generator connection scheme.

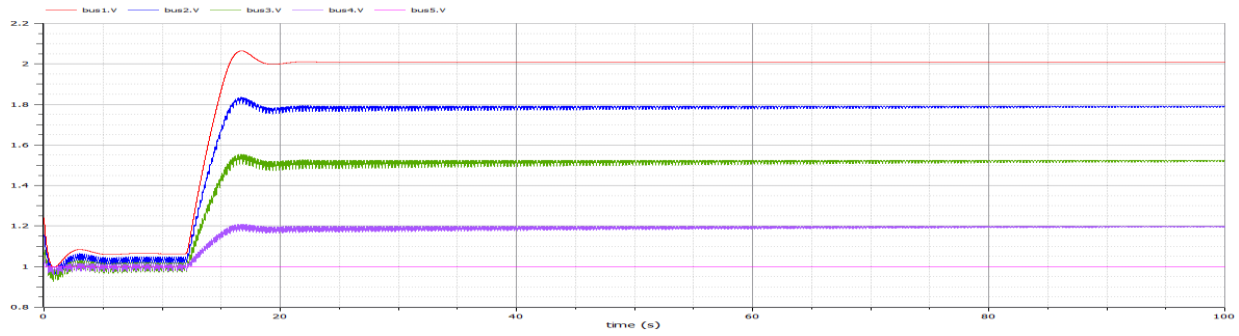

Figure 3: Voltage profile plots of all the five buses

Case 2: *Balanced 3 phase ground fault (5 to 5.1 secs)(refer to five_bus_system_case2)*

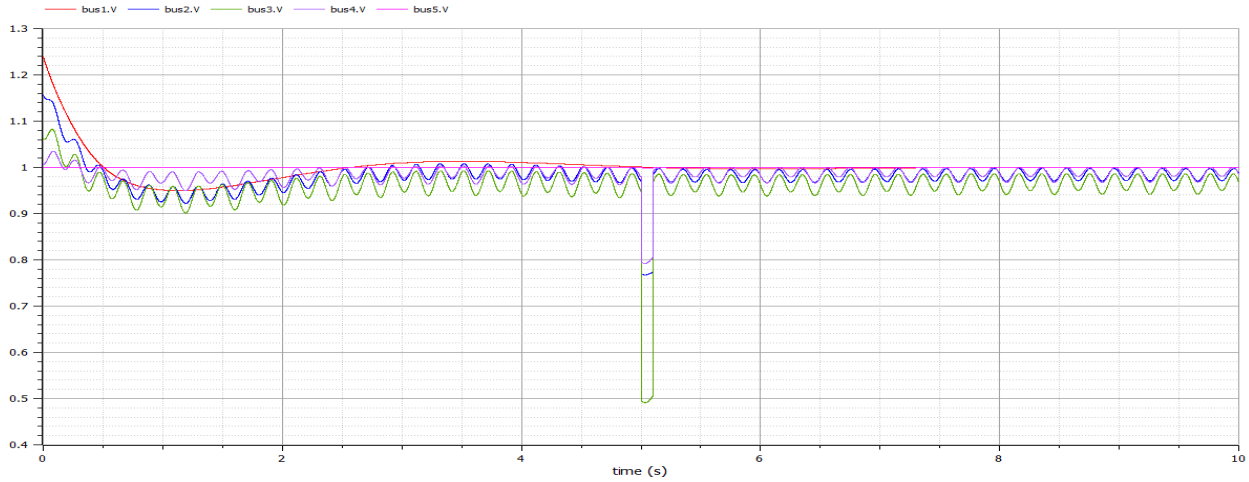

Figure 4: Voltage profile plots of all the five buses during fault conditions

In this model, the balanced three-phase ground fault is simulated at bus 3 for a duration of 0.1 secs starting from 5 secs and cleared at 5.1 secs. The voltage profiles are plotted (refer to figure 4). The severity of the fault is more at fault bus and minimum (almost negligible) at the generator buses. The generator buses are not affected by the fault as their terminal voltage is maintained by AVR. This can be also observed from the voltage profiles of bus 1 and bus 5 (generator buses). We can also observe that even after the fault is cleared the system consists of persistent oscillations in its voltage profile. These oscillations can be damped by using additional controllers (Turbine governor (TG) and Power system stabilisers(PSS)) on the generator's side.

Case 3: *Opening and reclosing of power line between bus2 and bus3 (refer to five_bus_system_case3)*

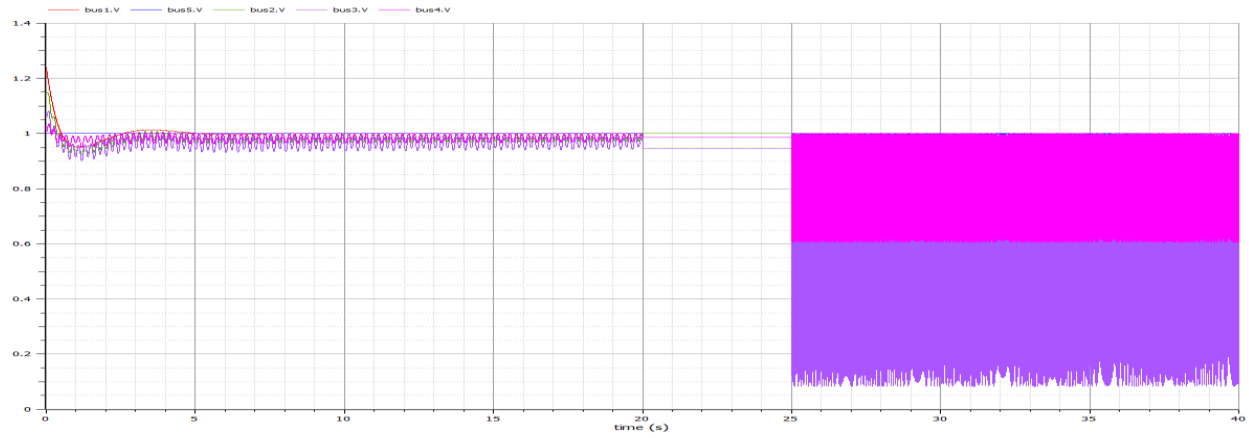

Figure 5: Voltage profile plots of all the five buses for case 3

In this model, the line between bus 2 and bus 3 (pwline2_3) is opened at 20 secs and reclosed at 25 secs. The voltage profiles for the same is shown in figure 5. We can see that the system becomes unstable after reclosure of the line. In this case, even the generator bus voltage start to oscillate but relatively these oscillations are of less magnitude. There is no parallel line connected where the power could be redirected and hence when the system becomes unstable. Voltage stability is concerned with the ability of a power system to maintain acceptable voltages at all buses of the system under normal conditions and after the occurrence of a disturbance. A system enters a state of voltage instability when a disturbance, increase in load demand or change in system conditions.

Conclusion:

The model represents the behaviour of the system under a three-phase ground fault condition, disturbances in field voltage by changing reference voltage in AVR and Opening and reclosing of the power line. In the case of reclosure of the power line, the system becomes unstable as there is no parallel line between bus 2 and 3 where the power could be redirected. In the case of a three-phase ground fault, the generator buses are not affected as their terminal voltage is regulated using AVR. In case of AVR disturbances at plant 1, the generator bus voltage at plant 2 remains unaffected.