BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

Course No. : EEE 206 **Section :** A1

Name of the Project: Modeling transient behavior of Sync Generator connected to an infinite bus using Simulink

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Group: 05
Level : 02
Term : 02

Objective:

The main objective of the project is to observe and analyze different types of transient behavior of a synchronous generator that is connected to an infinite grid and also analyze the stability criteria of the power generating unit from the transient behavior.Two different types of transient were considered in this project. These are-

i)Transient due to load switching and ii)Transient due to three or single phase fault.

Mainly, we observed the transient behavior of these two types separately and the combined behavior was also observed. By analyzing, different graphs were shown such as voltage vs time, current vs time, load angle vs time, power vs time.

By using Matlab Simulink, the project was set up and all kinds of analysis were done. The components required to simulate the project were Prime Mover Governor System, Main Field Excitation System, Synchronous Generator, Transmission Line, Power Transformer, Load, Infinite Bus etc.

All of these components were modeled in simulink for the purpose of analysis.

Components Analysis:

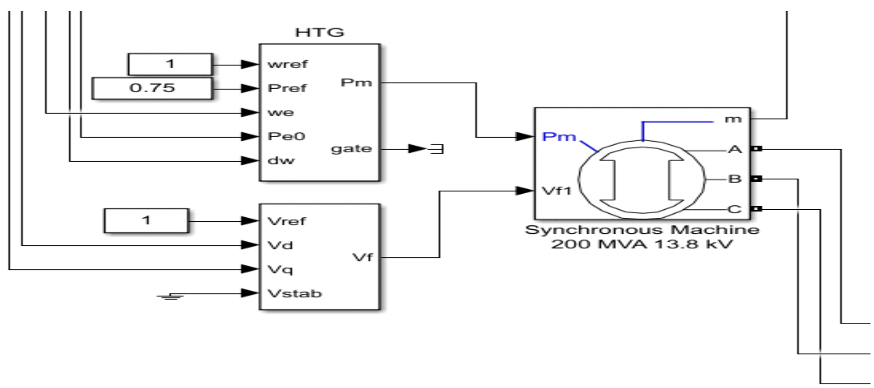
The Infinite Bus:

The infinite bus was modeled by a three phase Y connected generator of 100GMVA which is much larger than the unit that we will analyze. Here,

1. Line to line RMS voltage of the generator was taken to be 230kV.

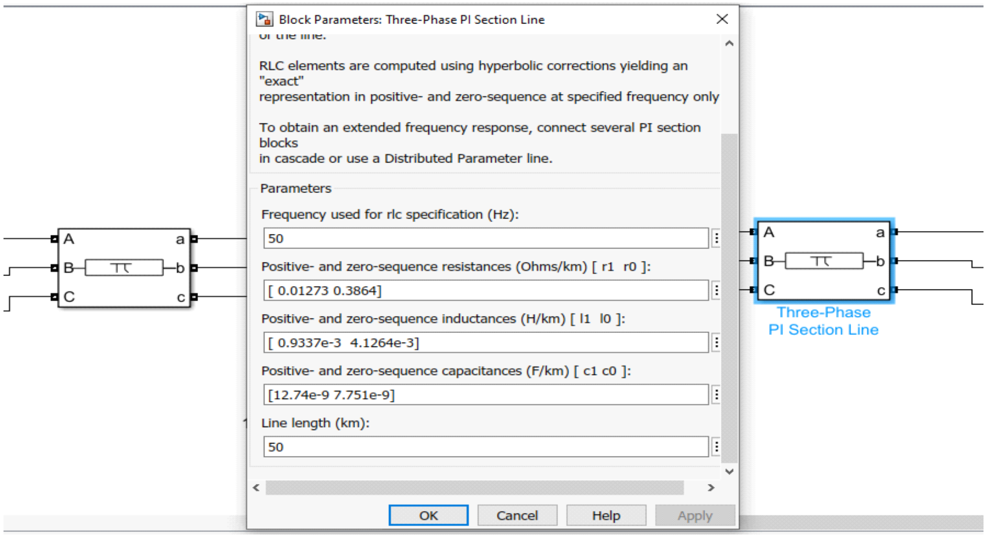
2. Frequency of the overall system was taken as 50Hz.

3. Neutral point of the generator was grounded for stability.



PI Section Transmission Line :

Transmission line was modelled using three phase pi section transmission lines from the simulink library. Length of each of the two transmission lines was taken to be 50km. So the sum of length of the two transmission lines was 100km. For switching surge studies involving high-frequency transients in the kHz range, much shorter PI sections (approximately line length is around 50km) should be used. A 'long' transmission line can be defined as any line exceeding approximately 200 to 250 km in length, although this is surely open to interpretation. In that case, we would need distributed line model. But as the sum of length of the two transmission lines does not exceed 250km we can use pi section instead of distributed



PI Section Transmission Line

line model.

Generator, Excitation System and Prime Mover:

Generator was connected to the transmission line through a power transformer. The primary side of the transformer was delta connected and the secondary side was Y connected. Neutral point of the secondary side was grounded. Transformer was a 13.8/230 KV step up transformer.

The generator was modeled using a salient pole 3 phase synchronous generator from the Simulink library. The generator takes 2 input, mechanical power and excitation field voltage. And it outputs 3 phase balanced voltage at its output terminal.

Excitation system takes 4 inputs**.** Reference voltage (V_{ref})**,** Direct axis voltage from Generator (V_d)**,** Quadrature axis voltage from the generator (V_q)**,** Ground connection (V_{stab})

It creates a field voltage for the generator.

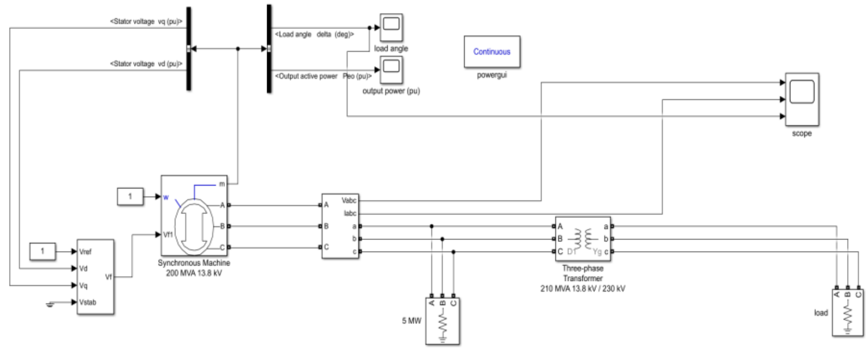
The prime mover governor system takes 5 input**.** Reference speed (W_{ref})**,** Actual speed of the rotor of the generator (w_e)**,** Speed deviation from the reference speed (dw)**,** Real output power of the generator (P_{e0}) Reference power limit (P_{ref})

It provides mechanical power to rotate the rotor of the Generator.

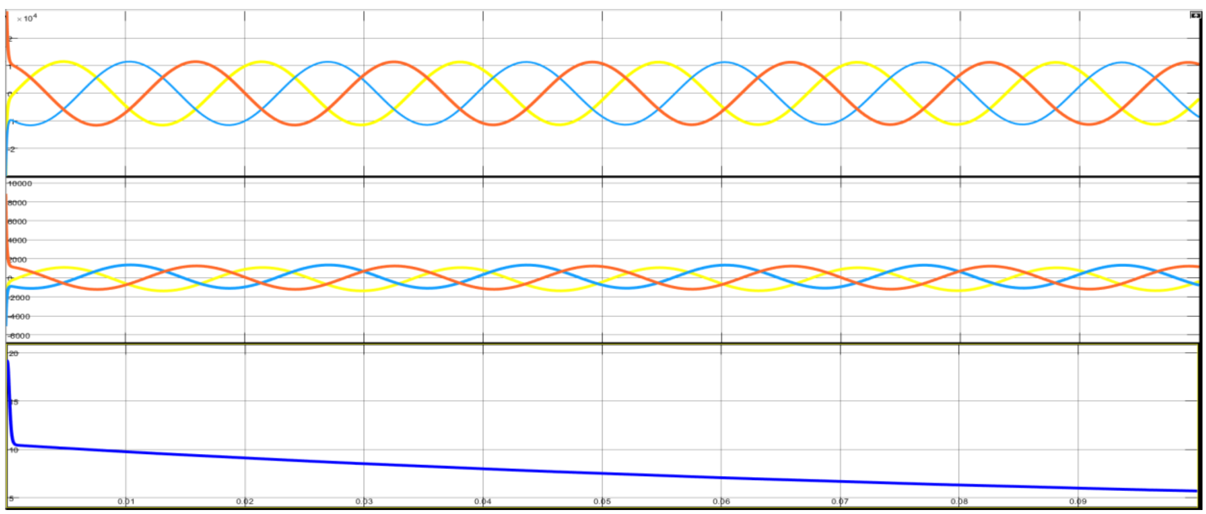
Working Procedure:

i) Steady State Analysis:

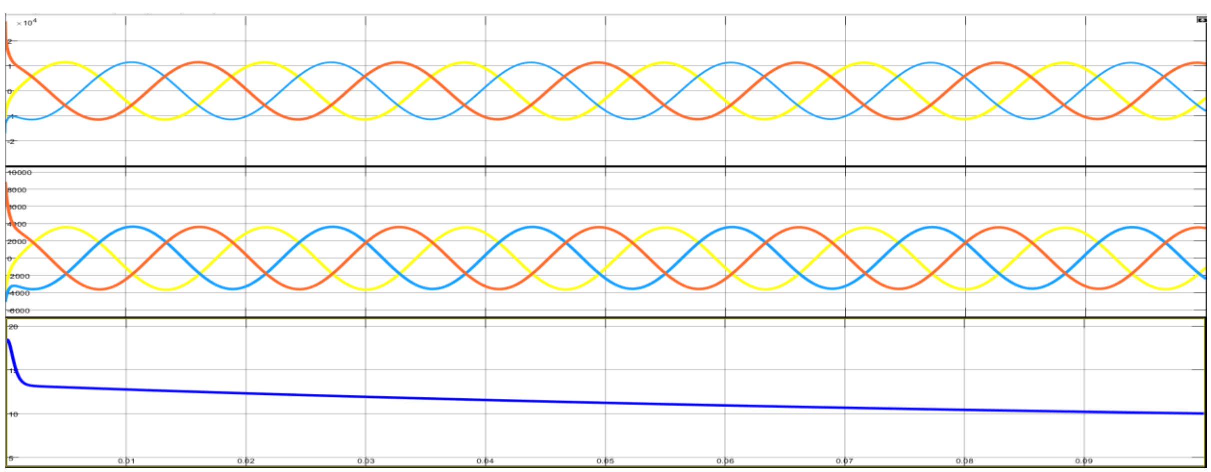
Before considering transient nature, we would like to explain how a synchronous machine behave in its steady state condition. To do so, we supply some load across it. Block diagram will be:



According to synchronous generator's nature, if we vary the load value armature current should vary accordingly. That means with the increment in the load armature current should increase. Also as power output depends on the load angle with load, load angle will increase too.Corresponding scope plot for terminal voltage, armature current and load angle for 15MW and 55MW is:



For 15MW



For 55MW

We see that terminal voltage amplitude remains constant while armature current and load angle raises with load which agrees with the theory.

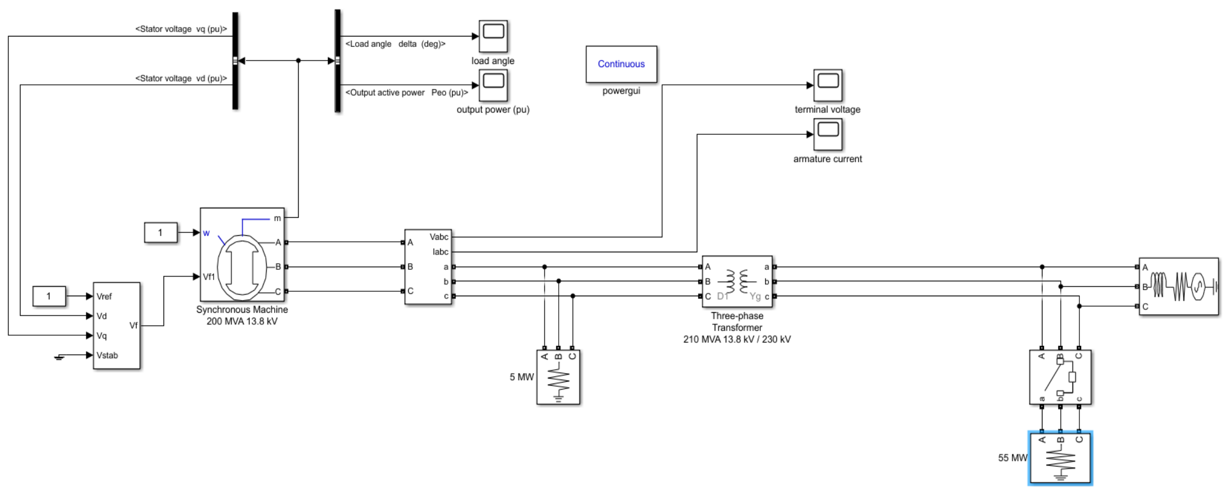
ii) Transient due to Load Switching:

From the steady state analysis we saw that when load changes, the load angle changes. But change of load angle doesn't happen instantaneously. Rather the load angle oscillates above and below the optimal value of load angle before settling down the required value. Also the stator current changes with different load. If load is increasing, the stator current will increase due to synchronous generator internal voltage remain constant. As load increasing, synchronous generator internal voltage swings up and it's tip far away from terminal voltage tips. As a result stator current and load angle increase.

If the load angle is increasing beyond 90 degrees, the synchronous generator is unstable due to exceeding static stability.

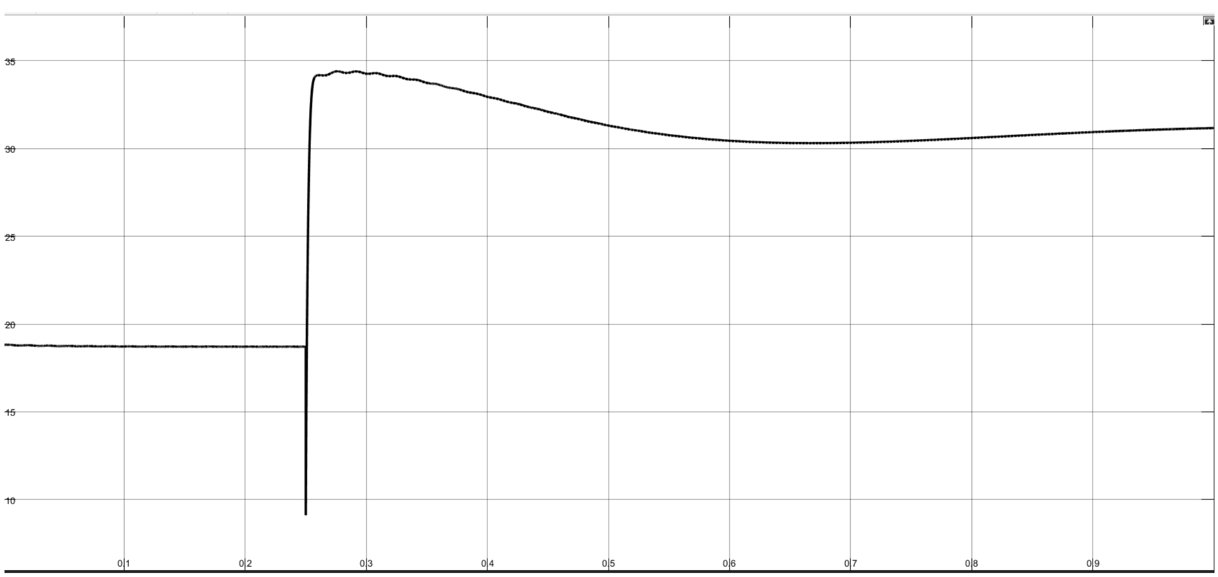
i) Load angle when load added(switching):

Block Diagram:-



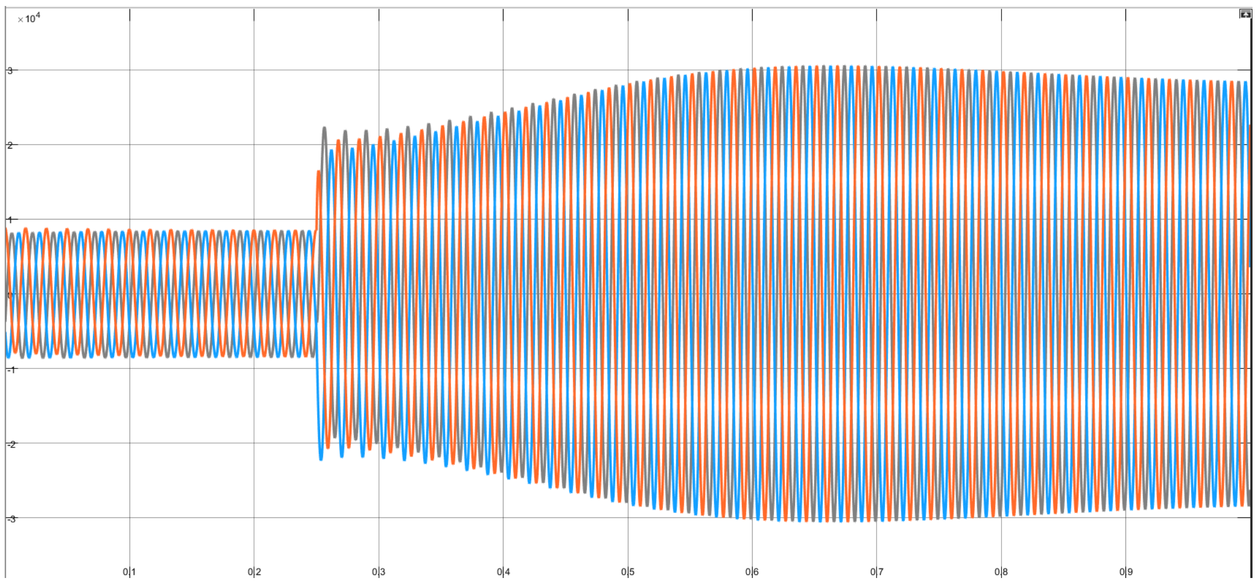
<u>Scope output:</u>

i) Load angle when switching (Here we apply the switching at 0.25 Second)



From the simulation graph we can see that the generator goes through transients when switching load. The load angle of the generator oscillates a few times before settling down to a fixed value that supplies the required power to the load.

ii) **Stator Current:**



Also we can see that every time we include a new load amplitude of current delivered by the generator increases.

Comparing Large load and Small load switching

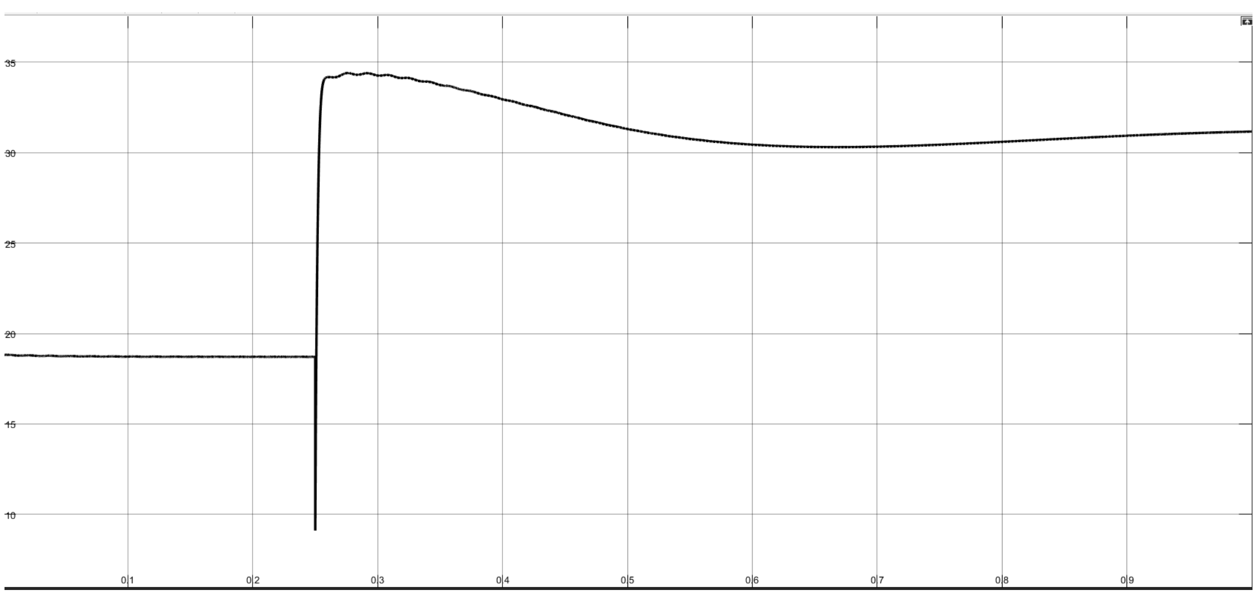


Fig: Large load(5000MW) switching

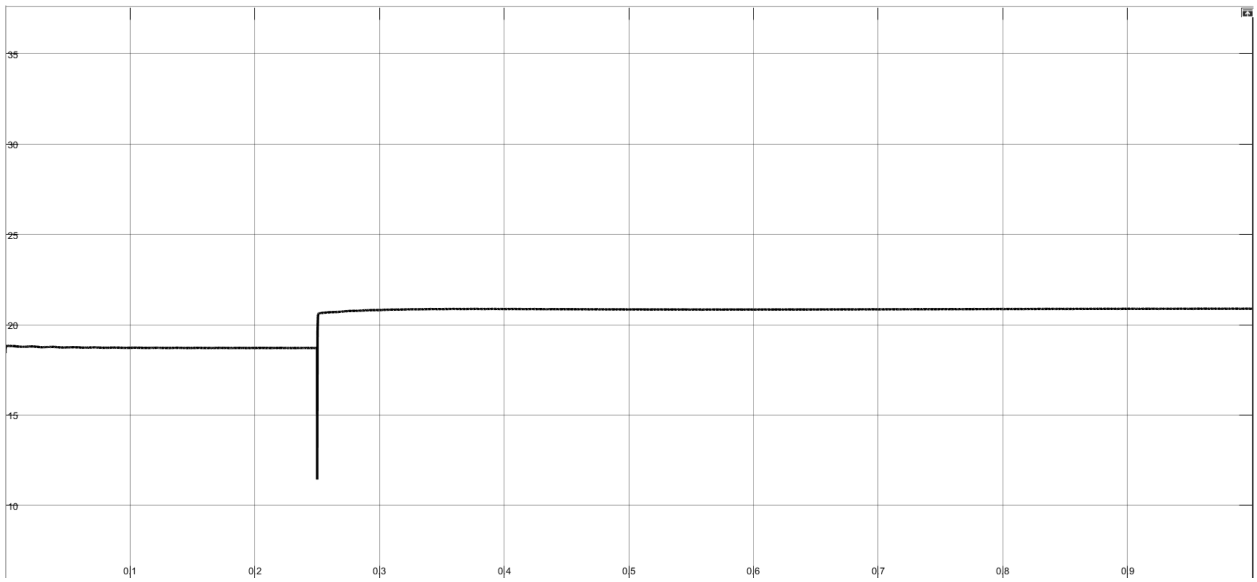


Fig: Small load(500MW) switching

Large load switching at 5000 MW remains high oscillation of load angle and falls to approximately 2.5 degrees with respect steady state condition.

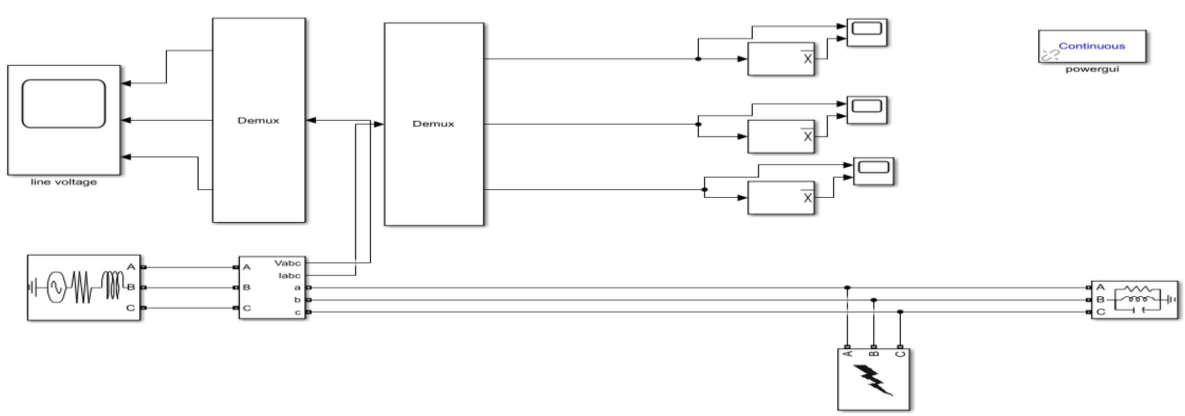
Small load switching at 500MW remains very low oscillation of load angle and falls to approximately 5 degrees with respect steady state condition.

Due to stability:

Also from the graph we can see that when we switch small load load angle doesn't oscillates much. But if we suddenly switch a very large load, the load angle oscillates to a very high value before settling to the optimum value. As we know the generator is stable if for all values of load, the load angle remains within 90 degree. So sudden switching of very large load value may lead to instability in power system. In this case if we divide up a very large load into multiple small loads and then switch them one by one then the load angle doesn't oscillate to a dangerously high value. And thus the power system always remains stable.

iii) Fault:

Block Diagram:



Fault can be applied in two different ways.

a) Symmetric Fault and b) Line to Ground Fault

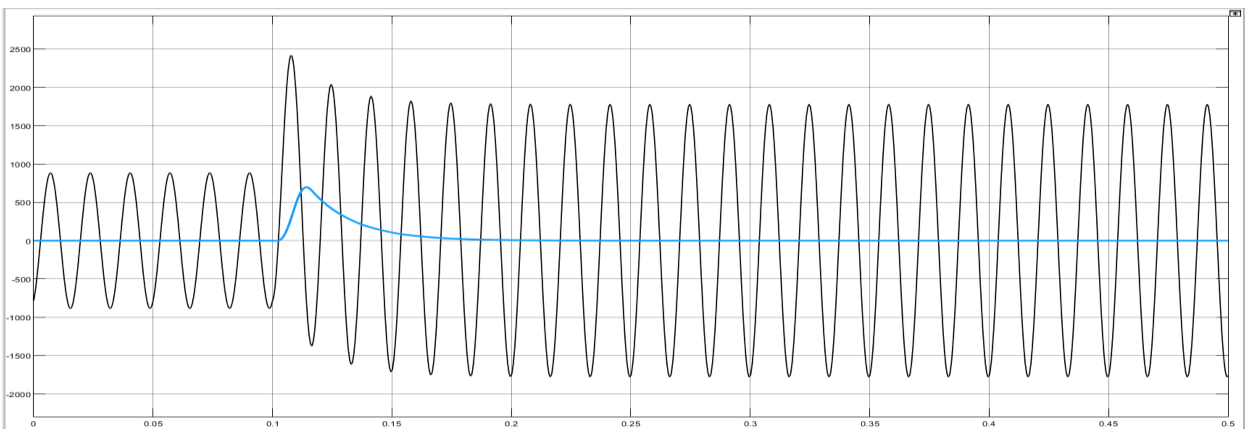
Now according to theoretical analysis, we know that a dc component will appear whenever a fault is introduced as it makes the appearance of the synchronous machine as a source to an inductor and inductor doesn't allow instantaneous change of current. This cause transient portion in the behavior.

Also the presence of damper winding in the synchronous machine construction causes the initial sub-transient part which is more severe than the transient part.

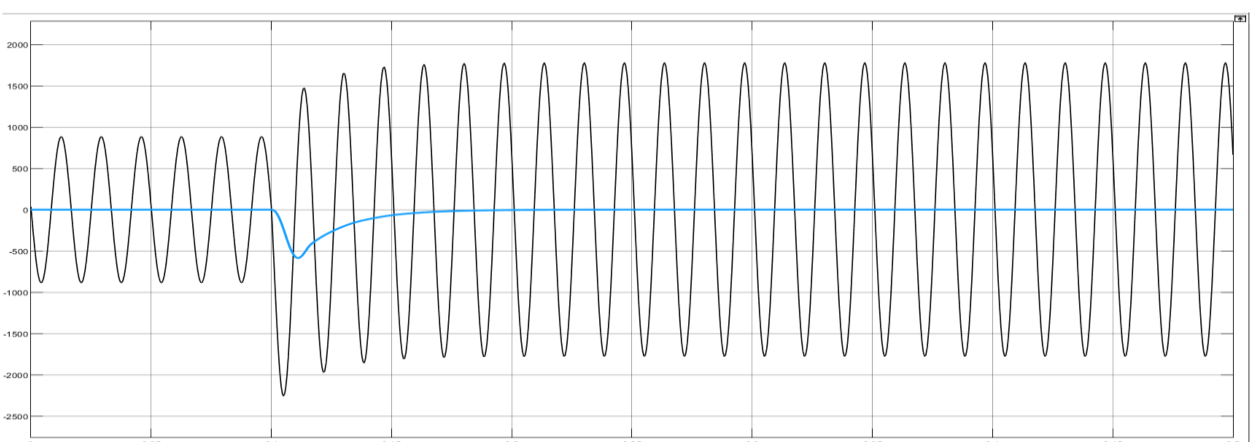
However with time this dc component will disappear and we get steady state output which amplitude will be higher than before fault.

At first, we will apply a symmetric fault at the sixth cycle. Let see the effect in three phase armature current after the fault is added.

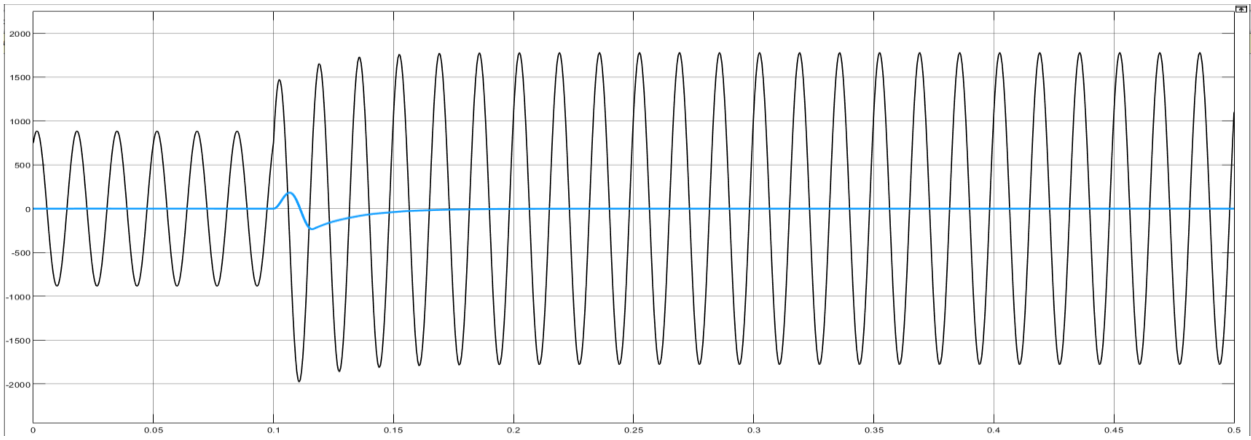
Phase A:



Phase B:

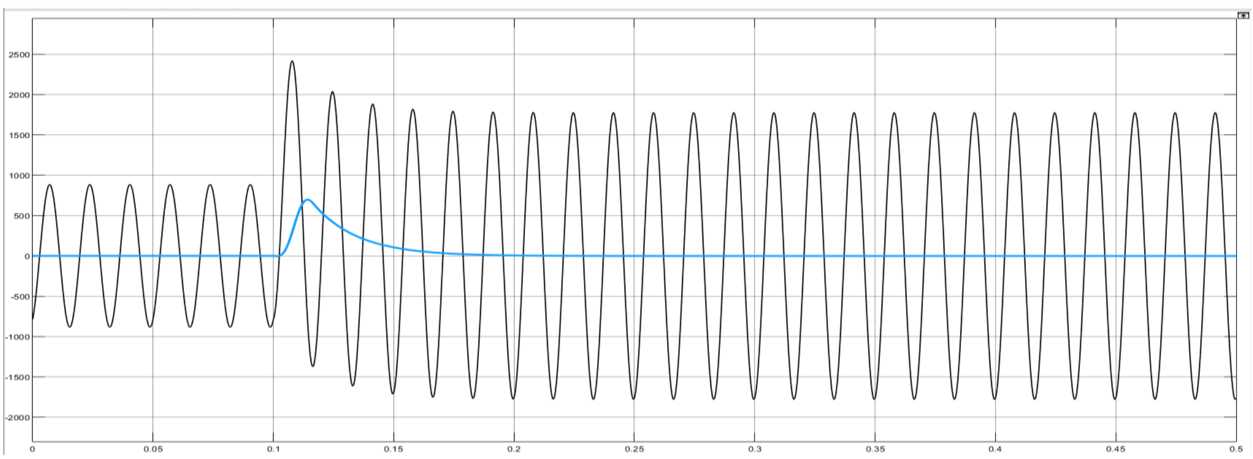


Phase C:

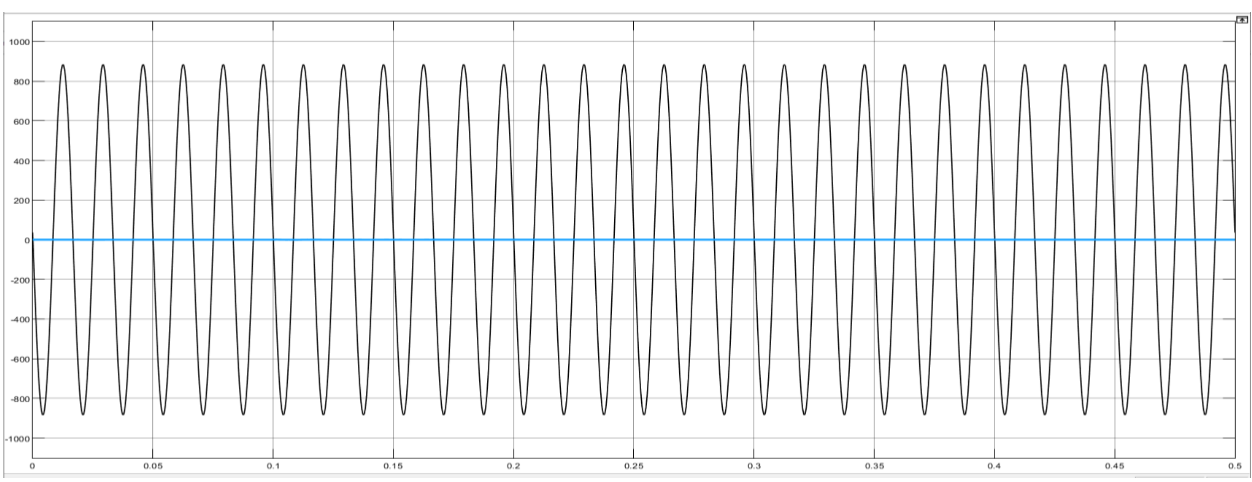


As the phase have difference in their phase angle, appearance of dc component was different for different phases which appears at the 6^{th} cycle and disappears with time. Now let see the effect of a single line to ground fault. Here we apply the fault only to phase A

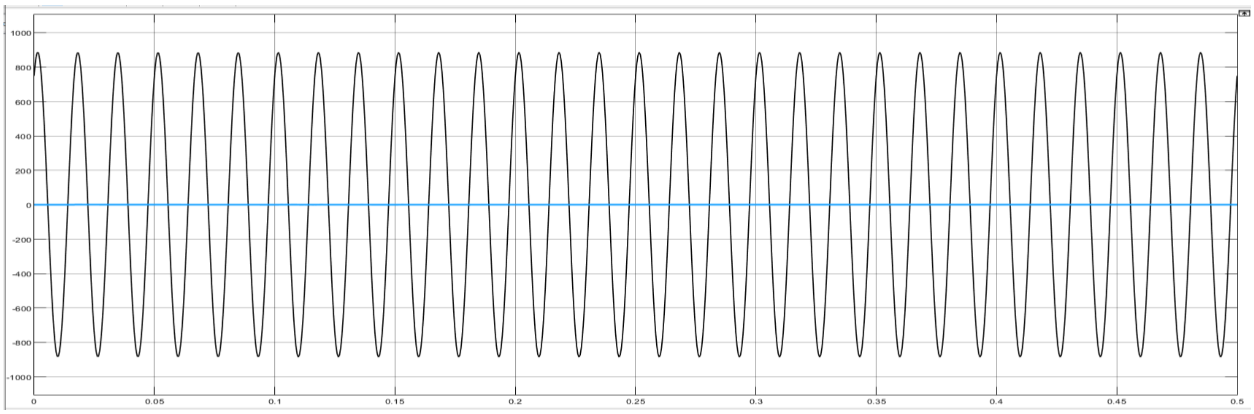
Phase A:



Phase B:



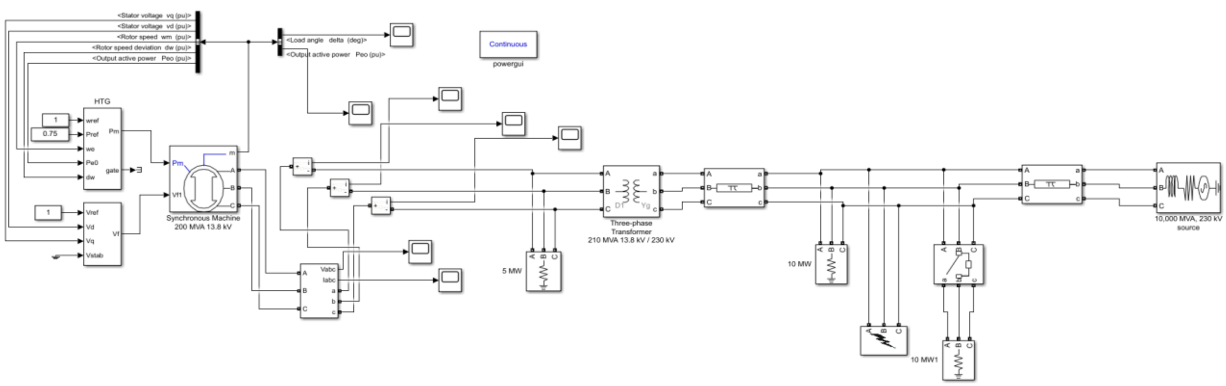
Phase C:



So, the dc component only appears at phase A.

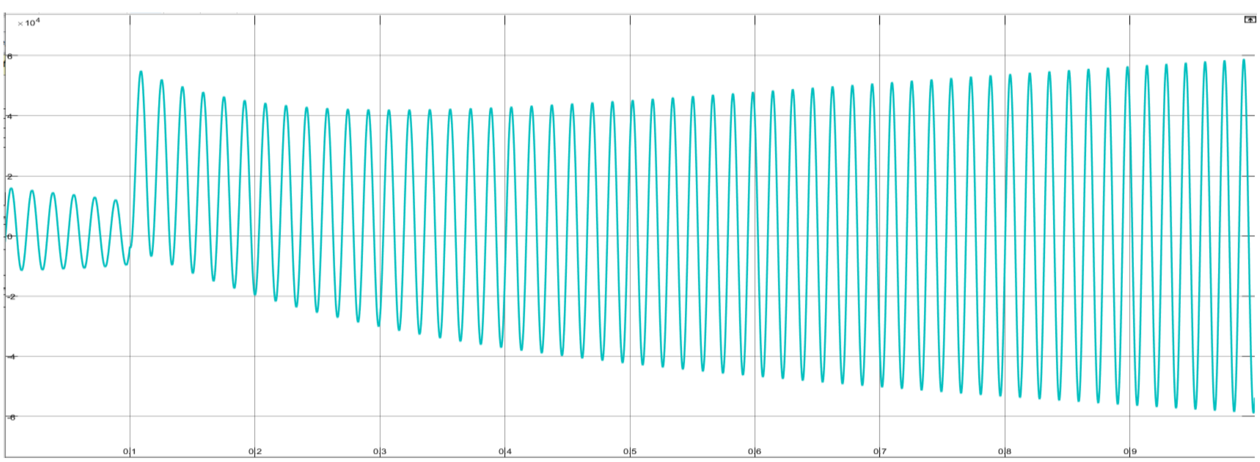
iv) Combination of Load switching and Fault:

Block Diagram:

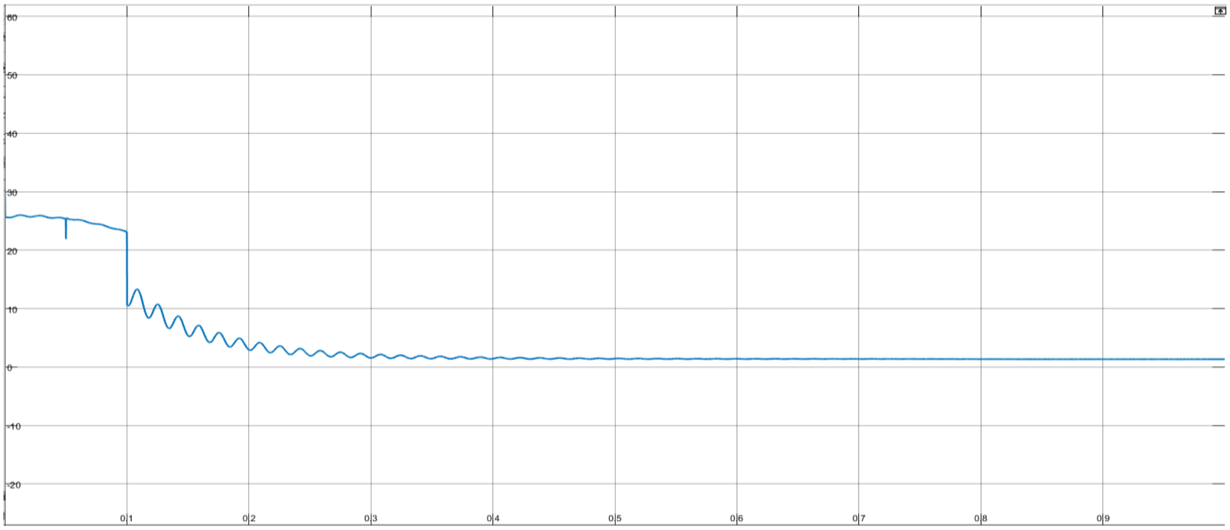


Here we will apply the load switching at the 3rd cycle and fault to the 6th cycle. Thus we should see transient effect at the corresponding cycle which will disappear later. Here we will see the corresponding armature current and load angle plot here.

Armature Current of a single phase:



Load Angle:



So, the transient behavior is more obvious in the load angle as we see two evident position of transient behavior. But as we are using a constant output governor system, armature current output was slightly different though if the simulation was continued for more time, steady state part would appear.

Discussion:

As we can see transient behavior of a synchronous machine can appear due to load switching and short circuit fault at the infinite bus. For sudden load switching, to synchronize the speed, we can see transient behavior at the load angle and armature current. The transient response was more serious for higher load.

Also a sudden incident of short circuit fault at the infinite bus with which the synchronous machine is connected will cause much serious transient response by creating a dc component. But this will also reduces and create a steady state behavior though the amplitude will still be higher than the pre-fault condition.