EE 351
Section AE

Lab Report 3

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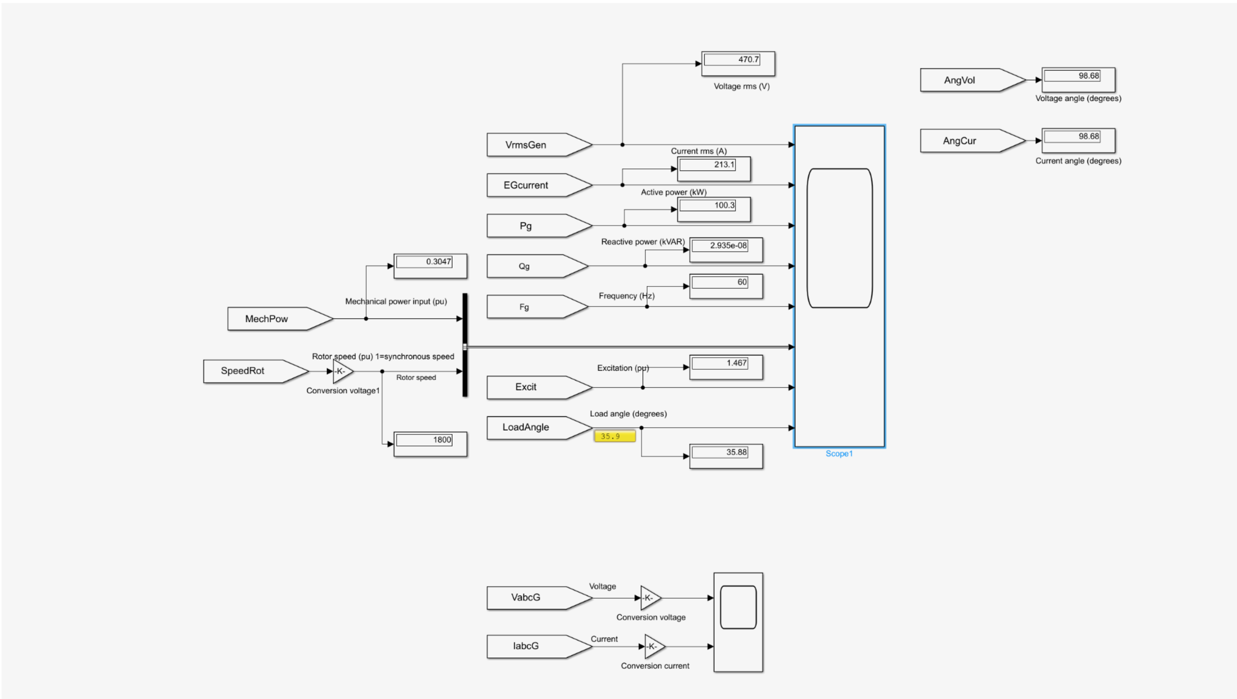
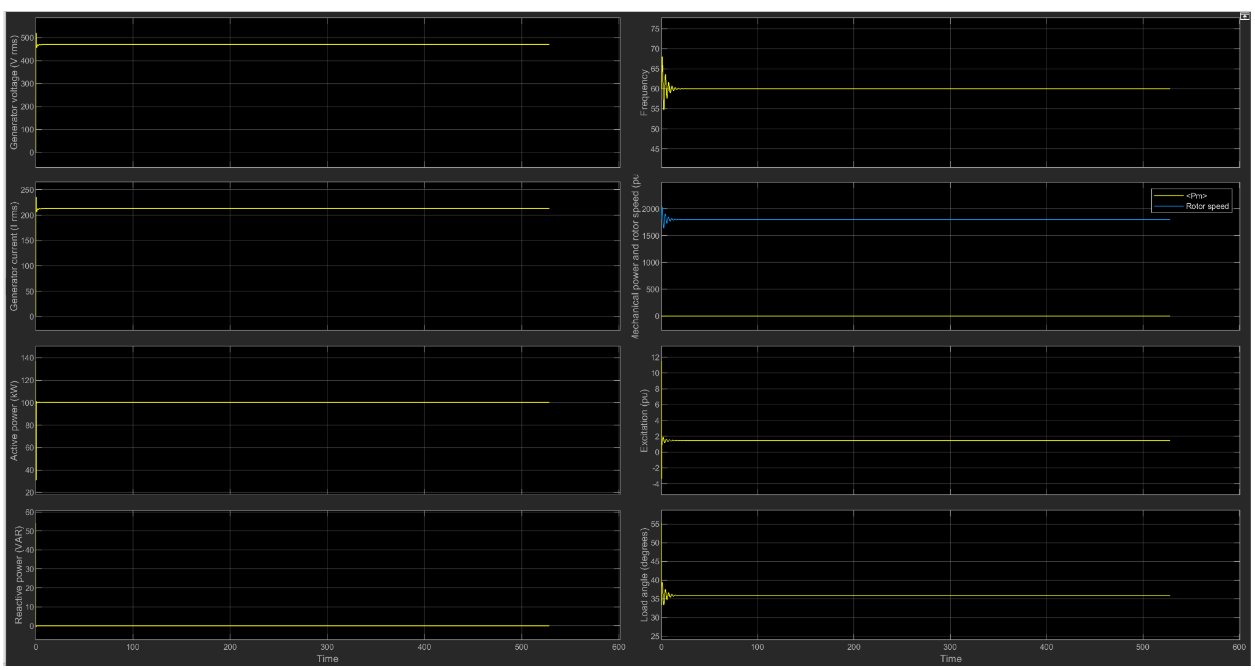
Part 1: Isolated generator

Initial Operating Condition:

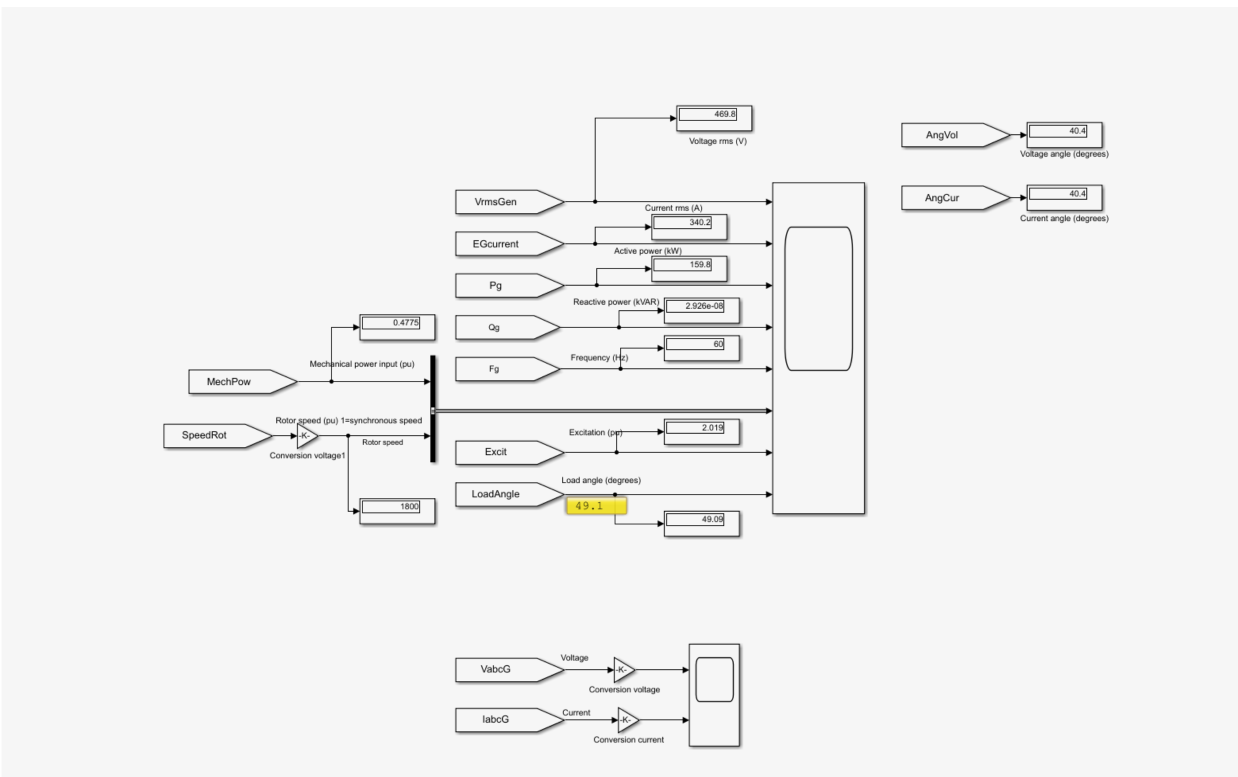


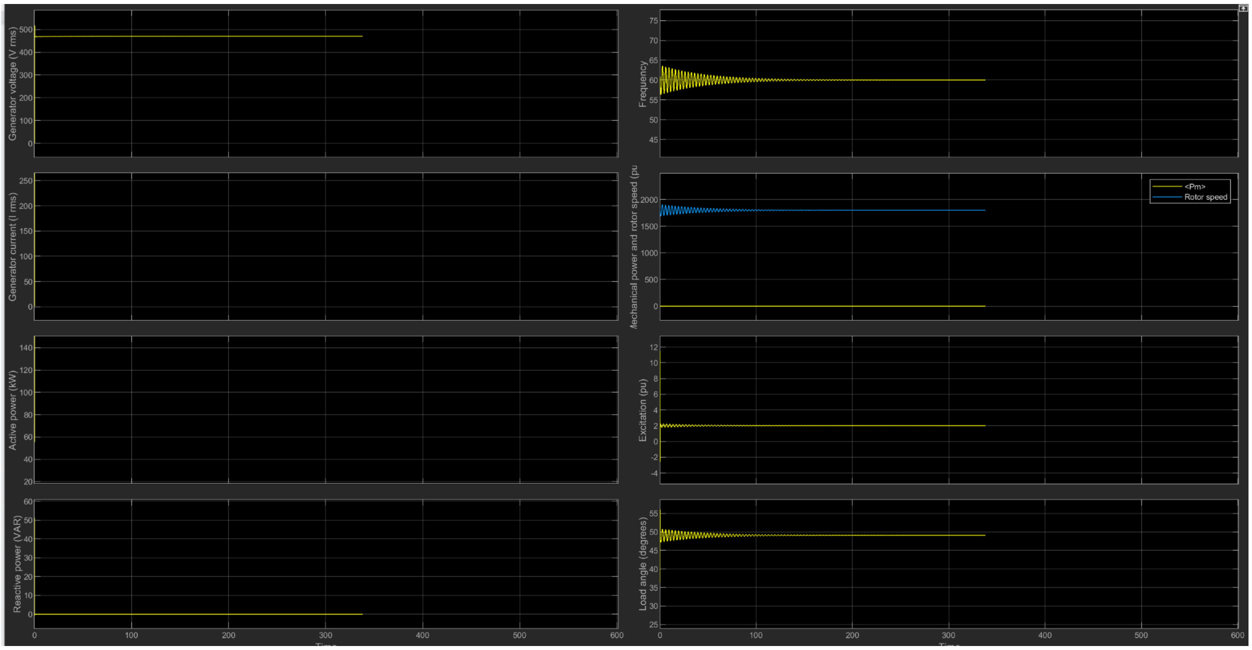


1. Active power load in kW = **100.3kW**
2. Reactive power load in kVAR = **2.935*10^-8 kVAR**

3. Active power generation in kW (this is same as the load) = **100.3kW**
4. Reactive power generation in kVAR (this is same as the load) = **2.935*10^-8 kVAR**
5. Magnitude of the voltage at the generator terminals = **470.7 V**
6. Frequency of this voltage = **60 Hz**
7. Magnitude of the current at the generator terminals = **213.1 A**
8. Rotational speed of the shaft of the generator (in RPM) = **1800 RPM**
9. Mechanical power provided by the prime mover = 0.3047*350k = **106.645kW**
10. Excitation voltage in per unit = **1.467pu**
11. Load angle in degrees = **35.9 degrees**

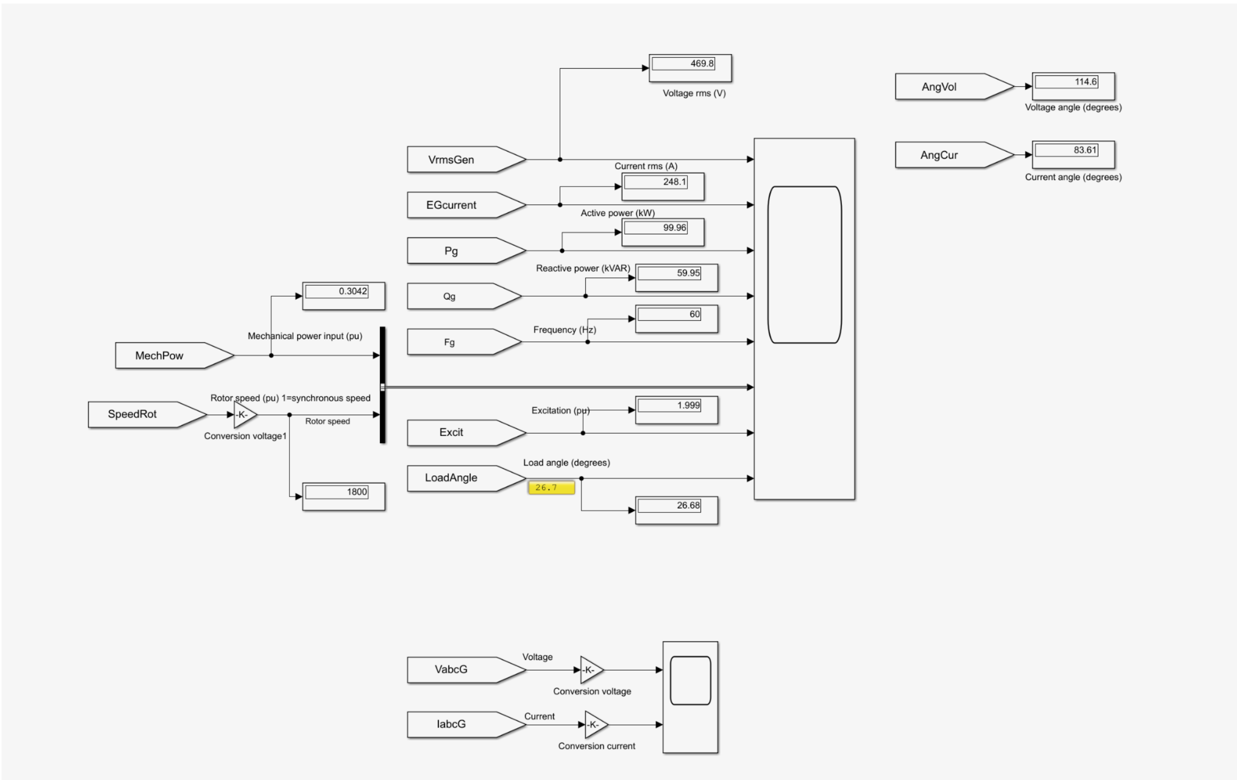
Operating Condition with active load is 160 kW:

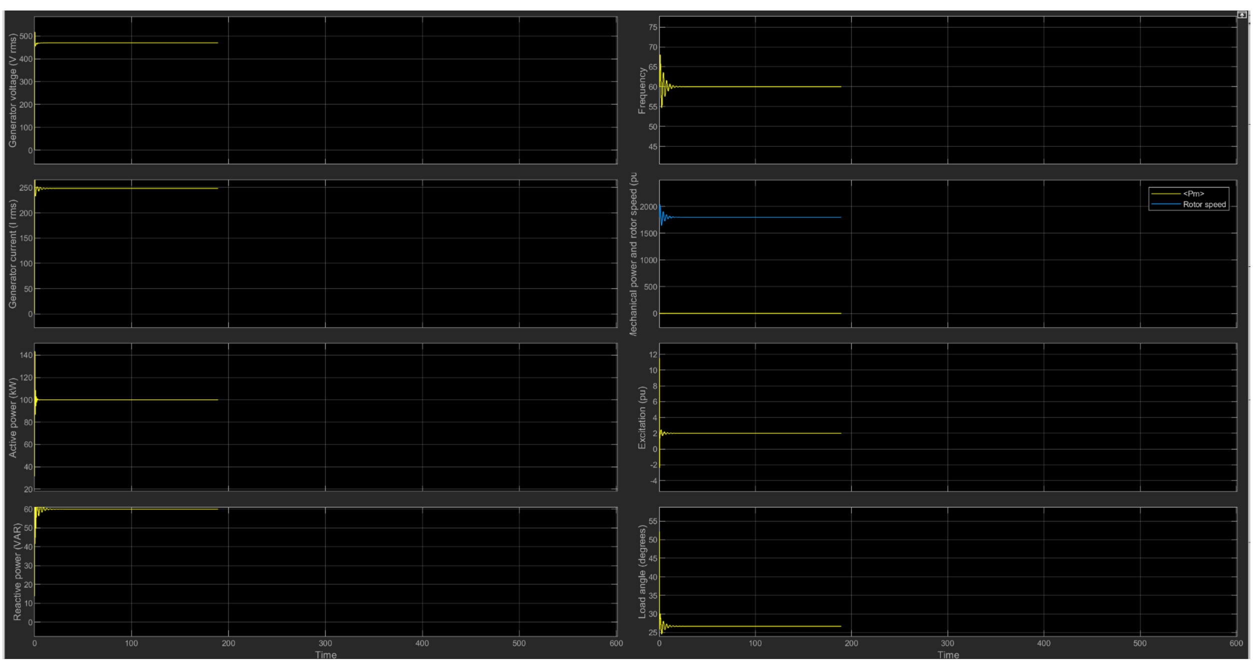




12. Active power load in kW = **159.8kW**
13. Reactive power load in kVAR = **2.926*10^-8 kVAR**
14. Active power generation in kW (this is same as the load) = **159.8kW**
15. Reactive power generation in kVAR (this is same as the load) = **2.926*10^-8 kVAR**
16. Magnitude of the voltage at the generator terminals = **469.8 V**
17. Frequency of this voltage = **60 Hz**
18. Magnitude of the current at the generator terminals = **340.2 A**
19. Rotational speed of the shaft of the generator (in RPM) = **1800 RPM**
20. Mechanical power provided by the prime mover = 0.477*350k = **166.95kW**
21. Excitation voltage in per unit = **2.021pu**
22. Load angle in degrees = **49.1 degrees**

Operating Condition with reactive load is 60 kW:





23. Active power load in kW = **99.96kW**
24. Reactive power load in kVAR = **59.95 kVAR**
25. Active power generation in kW (this is same as the load) = **99.96kW**

26. Reactive power generation in kVAR (this is same as the load) = **59.95 kVAR**
27. Magnitude of the voltage at the generator terminals = **469.8 V**
28. Frequency of this voltage = **60 Hz**
29. Magnitude of the current at the generator terminals = **248.1 A**
30. Rotational speed of the shaft of the generator (in RPM) = **1800 RPM**
31. Mechanical power provided by the prime mover = 0.3042*350k = **106.47kW**
32. Excitation voltage in per unit = **1.998pu**
33. Load angle in degrees = **26.7 degrees**

Discussion:

From results of above simulation, we see that by purely increasing the active load:

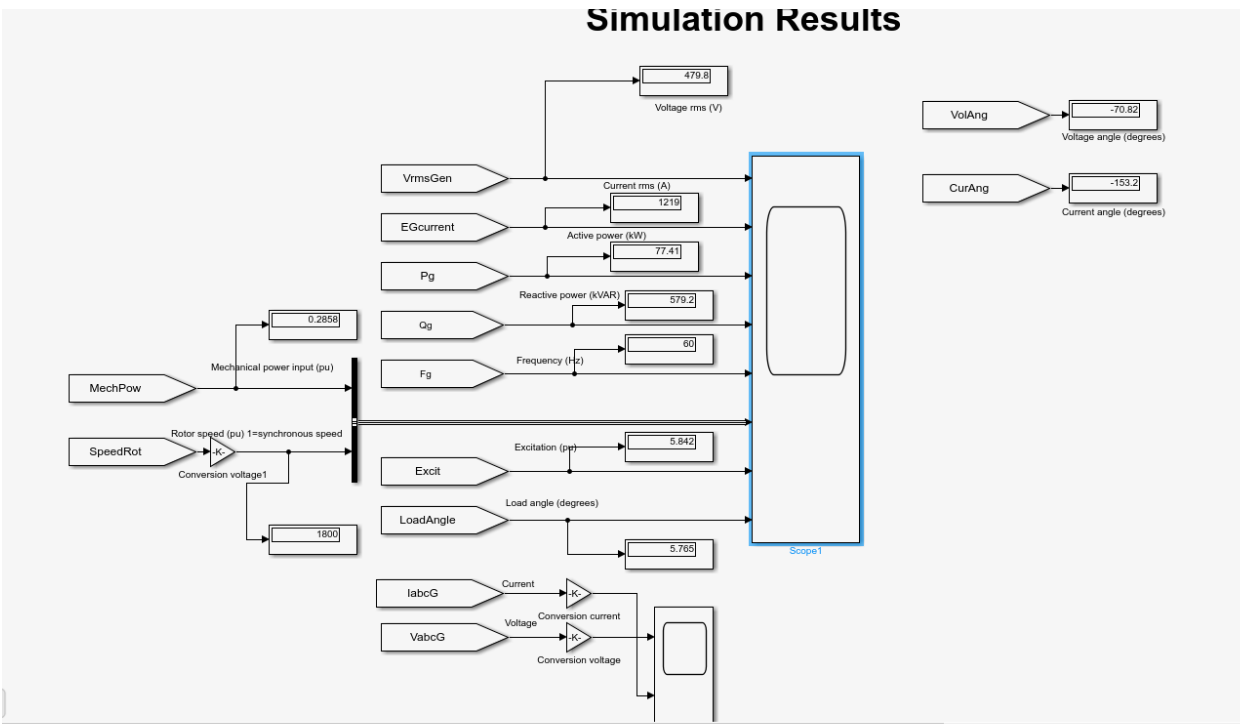
- The active power generation increases to the same as the active load power since this is an ideal generator that doesn't have any power loss;
- The reactive load power varies little since the reactive load wasn't changed;
- The magnitude of the voltage at generator terminal and frequency varies little since the isolated generator maintains the stator voltage and the frequency at rated value;
- The current increases significantly due to the voltage control loop. Since P increases, I have to increase to keep **V** the same as **P = VI**; this also makes sense since **I** = **V** / R where R is decreased to increase the active load and **V** is kept constant, indicating the current would increase.
- The load angle increases since θ = tan^-1 (Z_reactive / Z_active), when Z_reactive stays the same, Z_acitve increases;
- The excitation voltage increases slightly in order to keep **V** constant;
- The rotational speed of the shaft stays the same due to the frequency control loop;
- The mechanical power changes significantly to supply the active power in order to increase the active load;

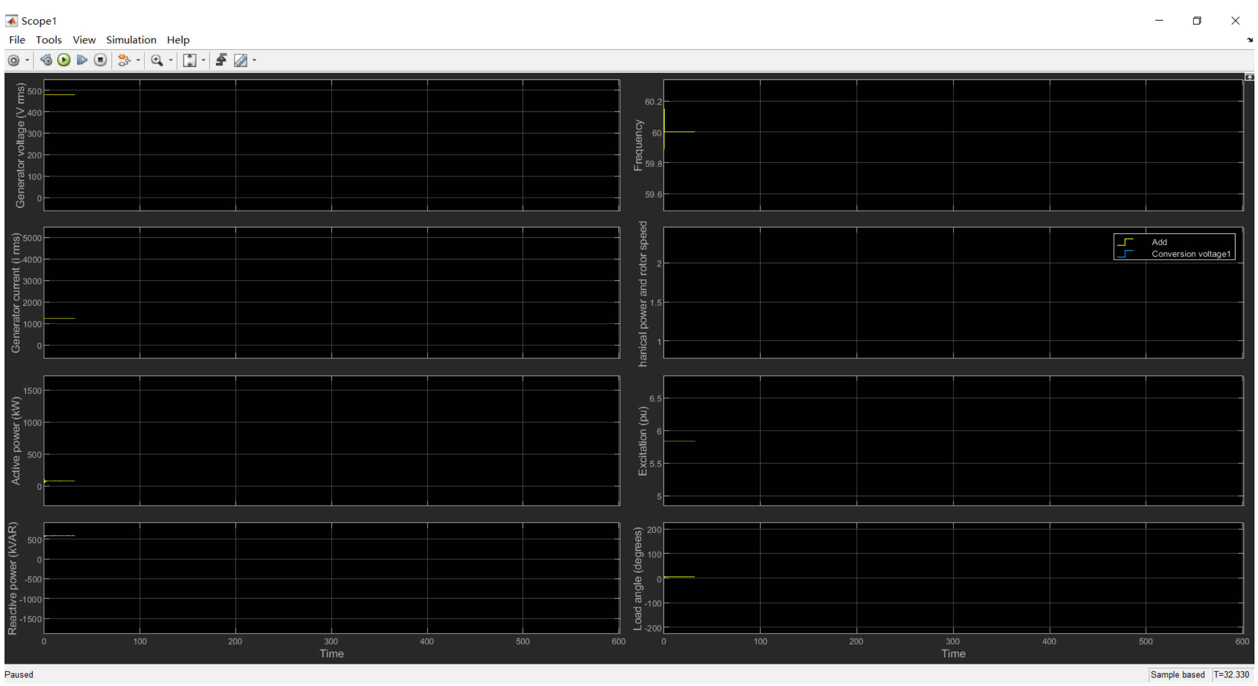
On the other hand, by purely increasing the reactive load:

- The active power generation varies little since the active load wasn't changed (as compared to first simulation);
- The reactive power increases to the same as the reactive load power since this is an ideal generator that doesn't have any power loss;
- The magnitude of the voltage at generator terminal and frequency varies little since the isolated generator maintains the stator voltage and the frequency at rated value;
- The current increases significantly due to the voltage control loop. Since P increases, I has to increase to keep V the same as P = VI;
- The load angle decreases since θ = tan^-1 (Z_reactive / Z_active), when Z_reactive decreases, Z_acitve is the same;
- The excitation voltage increases slightly in order to keep **V** constant;
- The rotational speed of the shaft stays the same due to the frequency control loop;
- Mechanical power varies little since reactive power is not real power;

Part 2: Grid connected generator

Initial conditions:

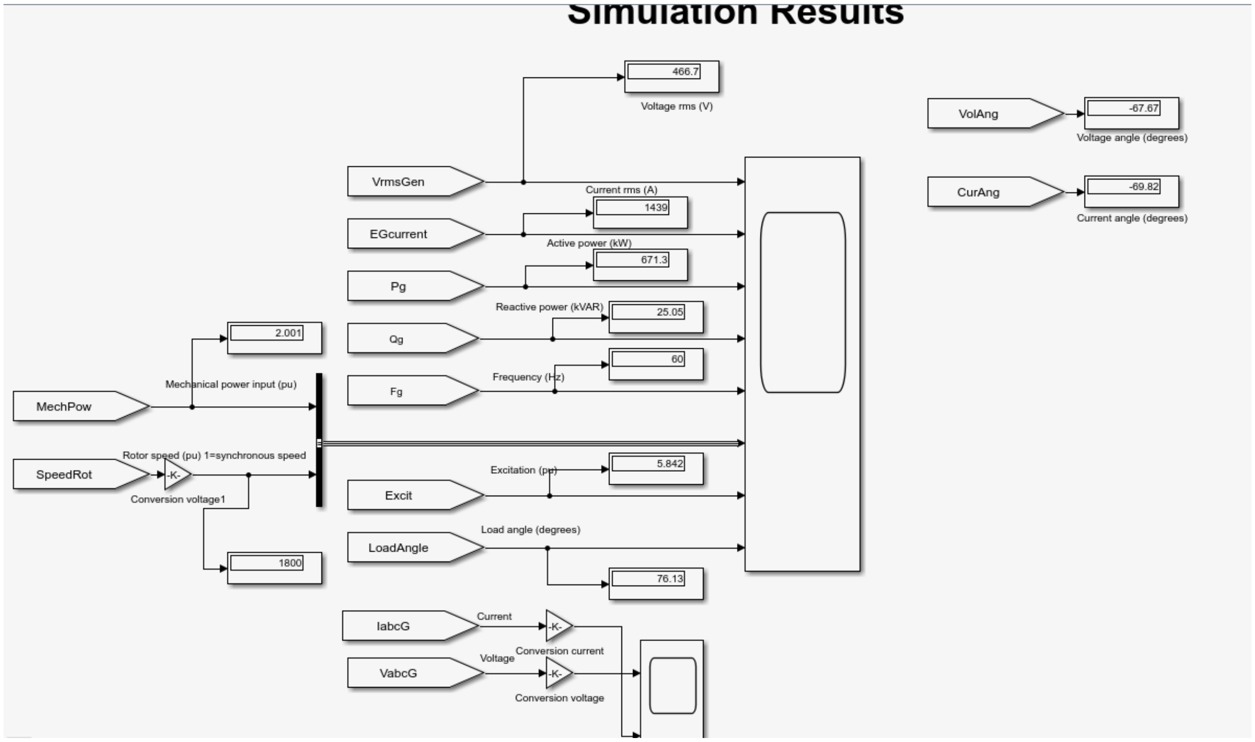




- Active power injected in the grid in kW = **76.17 kW**
- Reactive power injected in the grid in kVAR = **572.4 kVAR**
- Active power of the generator in kW = **77.41 kW**

- Reactive power of the generator in kVAR = **579.2 kVAR**
- Magnitude of the voltage at the generator terminals = **479.8 V**
- Frequency of this voltage = **60 Hz**
- Magnitude of the current at the generator terminals = **1219 A**
- Rotational speed of the shaft of the generator (in RPM) = **1800 RPM**
- Mechanical power provided by the prime mover = 0.2858*350k = **100.030 kW**
- Excitation voltage in per unit = **5.842 pu**

Operating Condition with mechanical power = 700 kW:



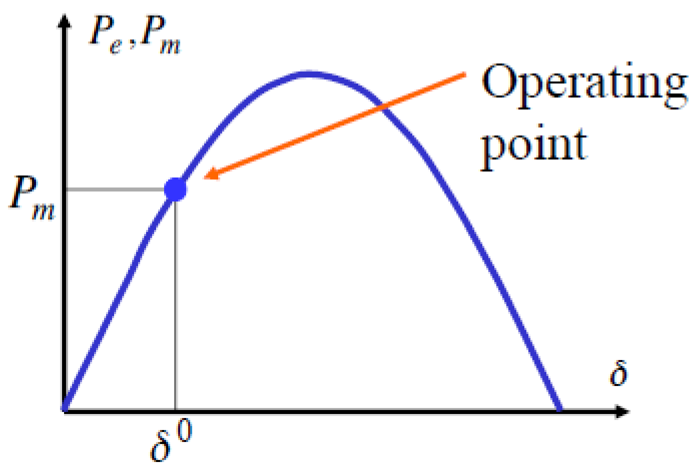
- Active power injected in the grid in kW = **670.1 kW**
- Reactive power injected in the grid in kVAR = **17.53 kVAR**
- Active power of the generator in kW = **671.4 kW**
- Reactive power of the generator in kVAR = **25.68 kVAR**
- Magnitude of the voltage at the generator terminals = **466.7 V**
- Frequency of this voltage = **60 Hz**

- Magnitude of the current at the generator terminals = **1439 A**
- Rotational speed of the shaft of the generator (in RPM) = **1800 RPM**
- Mechanical power provided by the prime mover = 2.001*350k = **700.35kW**
- Excitation voltage in per unit = **5.842 pu**

Discussion:

From the simulation, we observe that by increasing the mechanical power input of the generator:

- The mechanical power provided by the prime mover increases to about 700kW (this is what we've controlled);
- The frequency and magnitude of the voltage of at the generator terminals stay the same or varies little since this is a large grid and V is a fixed value, not impacted by power generated or E_f;
- Shaft speed stay the same as it cannot be changed;
- The active power injected in the grid thus increases significantly and the reactive power injected in the grid decreases significantly, same as the active power and reactive power of the generator: since the σ **increases with the input mechanical power as shown in the below graph, and P =** $\frac{V_t E_f}{X_S} sin\delta$ will increase due to sinσ and Q = $\frac{V_t}{X_s}\left(E_f \cos\delta - V_t\right)$ will decrease due to cosσ.



- The excitation voltage stays the same;
- The current increases. Since **P** = **VIcos(theta), P** is increased as discussed, **V** is kept constant, **I**'s real part must increase to keep **V** the same.
- Calculate the number of poles of this generator:

$$n_s = \frac{120f}{p} = \frac{120*60}{p} = 1800$$

, The number of poles P = 4

Contribution:
Experiments: Fan Yang, Simon Chen, Cynthia Li
Analysis of the results: Fan Yang, Simon Chen, Cynthia Li
Preparation of the report: Fan Yang, Simon Chen, Cynthia Li