TAMPERE UNIVERSITY
DEE-24106 Electric Power System

VOLTAGE STABILITY
Assignment - 2 Report

Name	ID
Md Nurunnabi Emon	281732
Sayad Mohammad Mahadi Hassan	281750

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1. Generator initialization:

Answer 1.1:

The variable initialization control, S2M, specifies the time at which the model transitions from source to a normal machine with all of its electrical equations 'active'. To ensure that the machine is operating as a pure source, the 'variable initialization control', S2M, has to be set to '0' until the required steady-state condition is attained.

Answer 1.2:

After the initial transients have settled, the machine mode is activated by switching S2M from 0 to 1. At this instant, the rotor will be spinning at a constant speed as the machine is still in the 'locked rotor' state. The governors and turbines may be initialized at the time instant when the rotor is unlocked, i.e. when the signal LRR is switched to 1. Once this happens, the mechanical dynamics is active.

Answer 1.3:

S2M and LRR are variables in Synchronous machine, Variable Initialization Data" submenu. They enabling dynamics of machine, fill them with values (0 or 1) for example with Time switch. We can erase them and fill this columns with values 0 or 1 (0=Source mode and Lock rotor Mode and 1= machine transition and Normal mode).

2. Load Models and Voltage Stability:

We have simulated the three cases using constant impedance load model and constant current load model. Data stored in a given excel sheet. The stored data is given below in Table- 1.

Table-1: Task 2 Simulation Results (give the voltages as p.u.-values)

S [MVA]	Constant impedance load			Constant current load		
	$U_{LoadBus110}$	$U_{LoadBus400}$	$U_{GenBus400}$	$U_{LoadBus110}$	$U_{LoadBus400}$	$U_{GenBus400}$
700	0.943	0.974	1.026	0.933	0.966	1.022
750	0.936	0.967	1.024	0.86	0.893	0.957
850	0.871	0.904	0.965	0.747	0.783	0.855

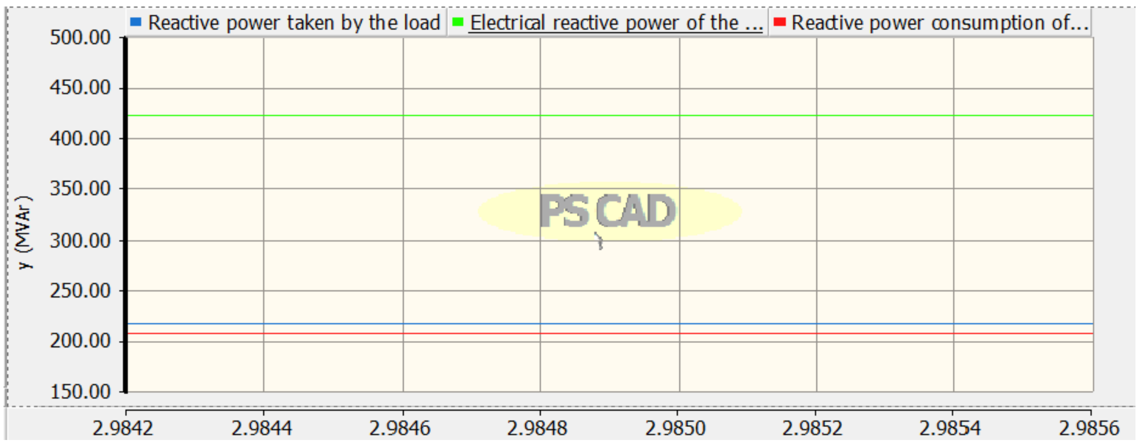
The real, reactive power taken by load and consumption by transmission line is given below in Table-2[A] using constant impedance load model and Table-2[B] using constant current load model. We zoomed the graph to observe the data.

Table-2 [A]: Simulation results

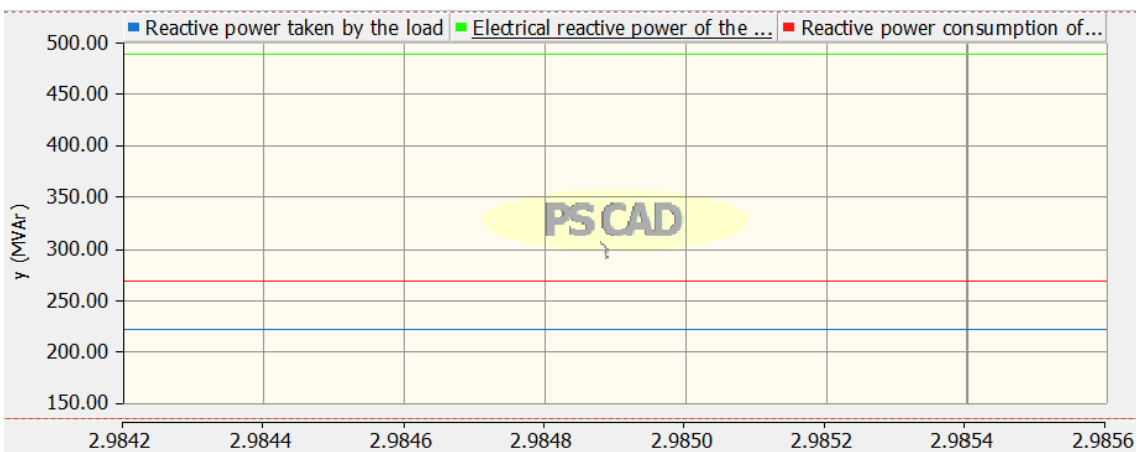
S [MVA]	Constant Impedance load				
	Reactive Power Taken by Load	Electrical Reactive Power of The Generator	Reactive Power Consumption of Transmission Line	Real Power Taken by Load	Electrical Real Power of The Generator
	[MVAR]			[MW]	
700	194.20	335.9	141.74	590.03	596.86
750	203.13	367.52	164.40	619.84	627.44
850	215.68	421.82	206.15	657.72	666.73

Table-2 [B]: Simulation results

S [MVA]	Constant Current load				
	Reactive Power Taken by Load	Electrical Reactive Power of The Generator	Reactive Power Consumption of Transmission Line	Real Power Taken by Load	Electrical Real Power of The Generator
	[MVAR]			[MW]	
700	204.15	368.20	164.07	620.85	628.43
750	211.20	407.31	196.76	644.48	653.14
850	220.27	487.31	267.03	671.73	682.35



[C] 850 MVA



[B] 850 MVA

Fig-1: [A] Using constant impedance load model and [B] Using constant current load model.

Answer 2.1:

Constant Current Load—the current stays constant as the voltage changes, and the power increases with voltage. As voltage decreases, the current draw stays the same, so the voltage drop does not change.

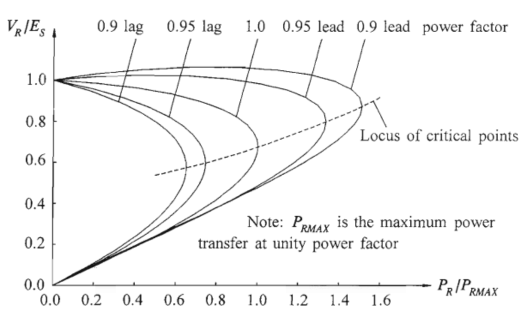
Constant Impedance Load—the impedance is constant as the voltage changes, and the power increases as the square of the voltage. As voltage decreases, the current draw drops off linearly, so the voltage drop decreases.

Reactive power consumption of transmission line depend on I^2X, here the current is constant in Constant Current mode, so reactive power drawn by the line is higher than in Constant Impedance mode, so the voltage at load end decreases in Constant Current mode. It's clearly seen from the Table-2[A], [B] and Fig-1 that the reactive power drawn by the line is higher at Constant Current mode than in Constant Impedance mode at the same apparent power level.

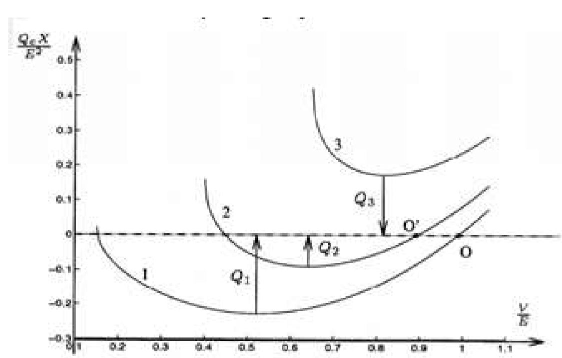
Answer 2.2:

A voltage collapse can be initiated by either a primary fault or an unexpected load demand increase, in combination with insufficient reactive power reserves or transmission capacity. Voltage is stable if it is located on the part of the PV or QV curve that is above the curve that gives maximum transmitted power. Maximum loading point is that where generator has the reaches its maximum reactive power limit and beyond that limit loses its control over voltage and voltage collapse.

Normally only the operating points above the critical points represent satisfactory operating conditions. Sudden reduction in the power factor can thus cause the system to change from a stable operating condition to an unsatisfactory, and possibly unstable, operating condition represented by the lower part of a V-P curve.



The V_R-P_R characteristics of the system



So in our network, even though the voltage is below 0.9 p.u but it will not unstable since the maximum power is in within the maximum active and reactive power limit. For $V_R = 0.747/1$ and $P_R/P_{RMAX} = 562.176/850 = 0.66$ pu which shows that still we are in the limit of stability. Generator is able to supply the necessary reactive power to maintain the voltage in the stable limit.

3. The effect of On-Load Tap-Changer (OLTC) on voltage stability:

3.1 Simulation Results:

We have simulated the three cases using constant impedance load model and constant current load model. Data stored in a given excel sheet. The stored data is given below in Table- 1.

Table-3: Exercise 3.1 simulation results (give the voltages as p.u.-values)

S [MVA]	Constant impedance load			Constant current load		
	$U_{LoadBus110}$	$U_{LoadBus400}$	$U_{GenBus400}$	$U_{LoadBus110}$	$U_{LoadBus400}$	$U_{GenBus400}$
700	0.956	0.966	1.02	0.919	0.872	0.939
775	0.907	0.86	0.927	0.775	0.743	0.822
850	0.846	0.809	0.879	0.715	0.691	0.772

Answer 3.2:

Table-3 [A]: Simulation results with OLTC

S [MVA]	Constant Impedance load			
	Voltage on Load Bus	Voltage on HV Side of 400/110 kV Trafo	Reactive Power Taken by Load	Real Power Taken by Load
	[pu]		[MVAR]	[MW]
700	0.956	0.965	216.01	608.74
775	0.907	0.860	198.66	604.18
850	0.846	0.809	190.85	582.02

Table-3 [B]: Simulation results without OLTC

S [MVA]	Constant Impedance load			
	Voltage on Load Bus	Voltage on HV Side of 400/110 kV Trafo	Reactive Power Taken by Load	Real Power Taken by Load
	[pu]		[MVAR]	[MW]
700	0.943	0.974	194.20	590.03
775	0.922	0.956	208.10	632.95
850	0.871	0.904	215.68	657.72

For every tap changing, power demand increases in the case of a voltage dependent load when restoring the voltage feeding the load which gives a current increase on the load side of the transformer and that increase voltage drop over the line, as a voltage dependent, load will decrease as the voltage decreases and power consumption decrease by the load decreases, see Table-2 [A] and [B].

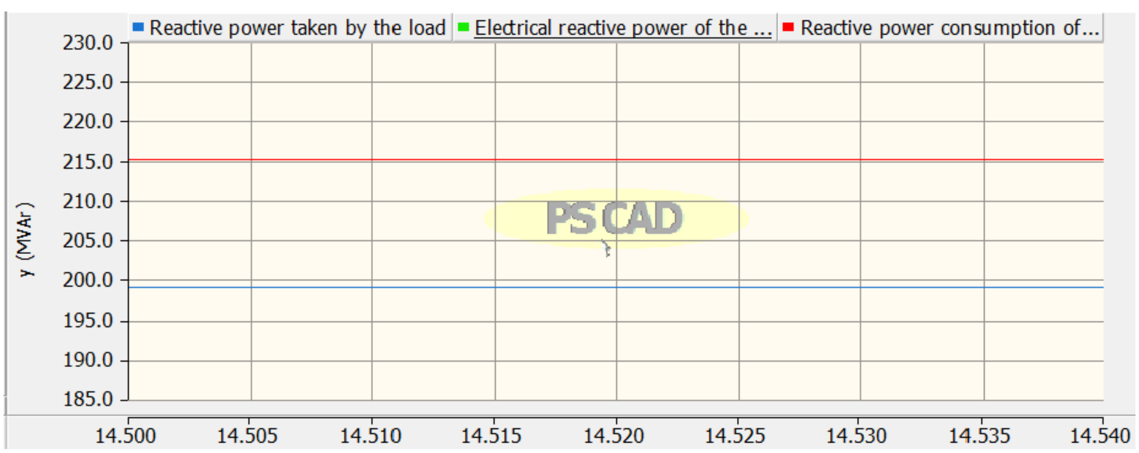


Fig-2 [A]: Reactive power consumption with OLTC

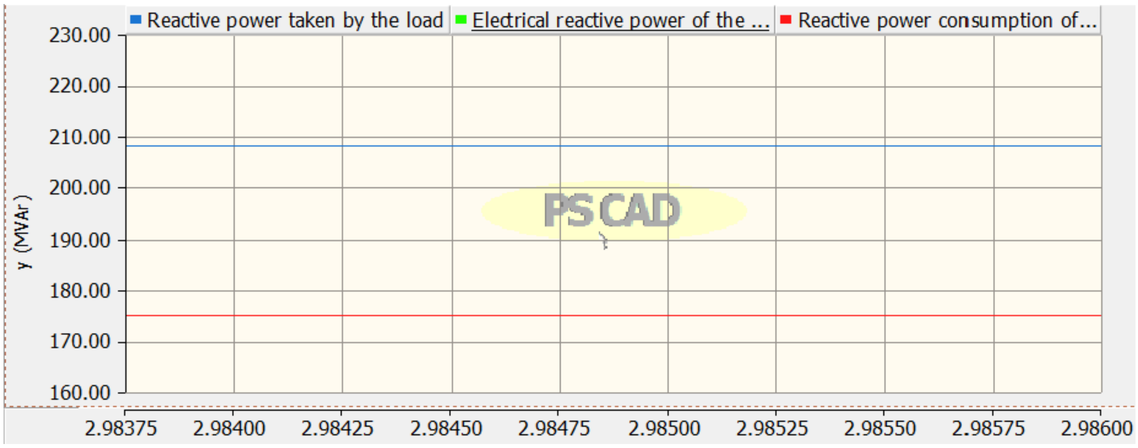


Fig-2 [B]: Reactive power consumption without OLTC

As the secondary side voltage goes up the primary side voltage goes down which leads to increase current. Since the reactive power consumption of line depend on I^2X, hence reactive power consumption by the line increases, see Fig-2. For three phase load with nominal power P=808MW and Q=265MVAR the reactive power consumption of line is about 215.11 MVAR with OLTC and about 175.01 MVAR without OLTC.

Answer 3.3:

Voltage instability occurs when there is disturbance in the system or increase of power demand for increase of load. The instability is the inability for the power system not to meet the demand for reactive power. The receiving side power increases rapidly then slowly decrease as demand for power of load increases. A system with On-Load Tap-Changer (OLTC) will try to raise the load side voltage which will cause more I^2X and I^2R losses of transmission line, which will lead to more voltage drops.

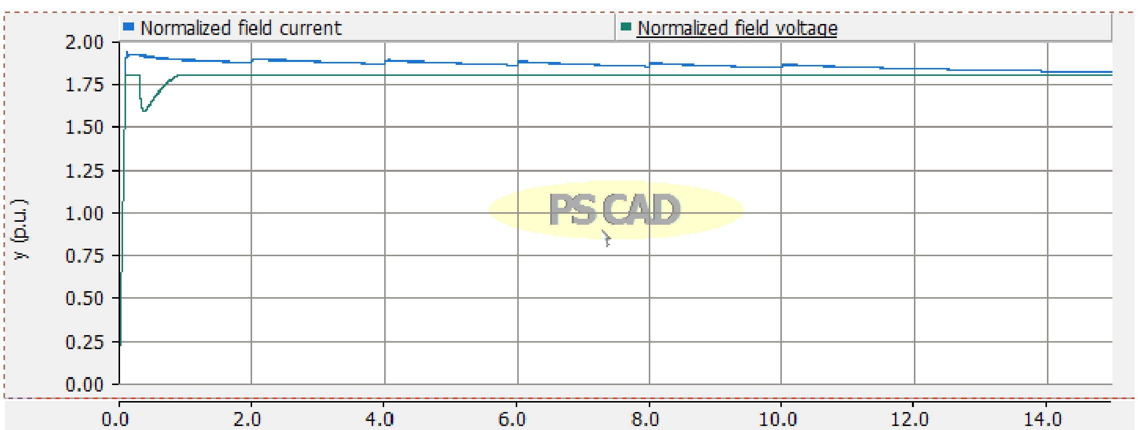


Fig-2: The generator field current and voltage.

With each tap changing the reactive output of the generator throughout the system would increase. Generally, generator will hit their reactive power capability limits but when generator reached its field current limit, its terminal voltage would drop, see Fig-2. As the voltage reduces, the deficit in reactive power increases and the voltage falls even further until it eventually falls to a very small value. This is called voltage collapse. Because of the OLTC the actual voltage collapse may occur later while the voltage instability already occurred.

To explaining this part we considered the three phase load with nominal power P=808MW and Q=265MVAR.

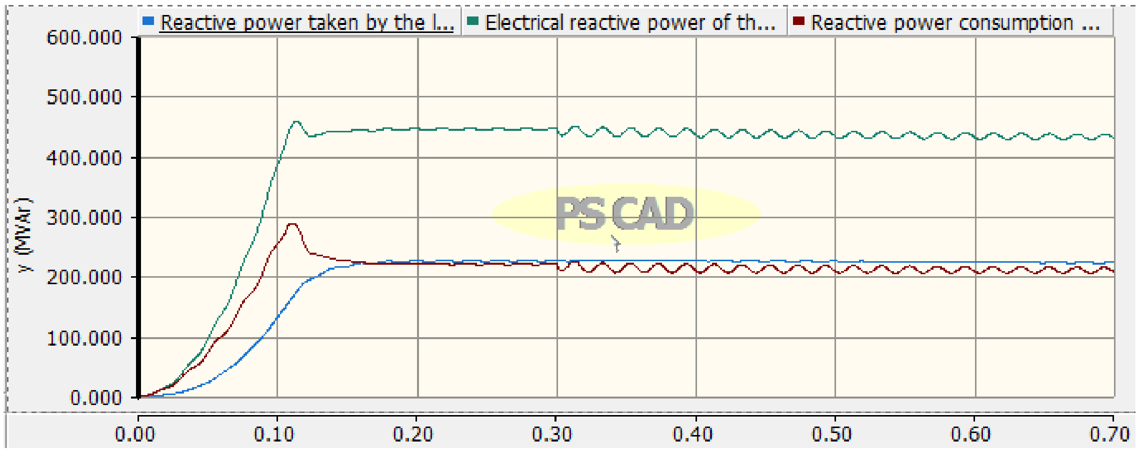


Fig-3: Reactive power generation and consumption.

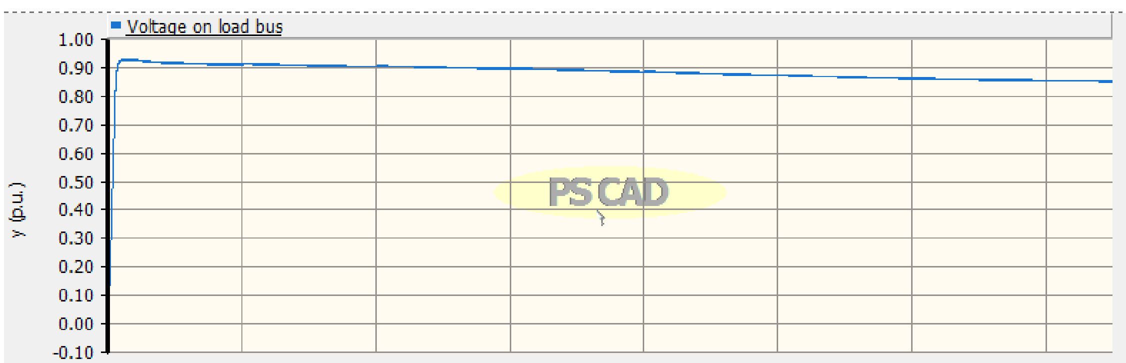


Fig-12: Voltage on Load bus.

As the load increases beyond the maximum power capability, the demand for reactive power become higher than production so voltage goes down. Our system's OLTC tries to boost up voltage but this increases load demand more which cause more loss in the transmission line so more voltage drops, see Fig-3. But this voltage instability is very lengthy to finally decide as voltage collapse hence the system is still operating at a value of 0.848 pu. from Fig-12. The system does not collapse because the generator can still meet the reactive power demand of the load. But in real there should be a relay to disconnect the line at a value of voltage than acceptable limit of 0.9p.u. So our system is partially voltage collapsed system so it may go towards zero after a long time or if we increase the load in heavy amount it may collapse immediately.