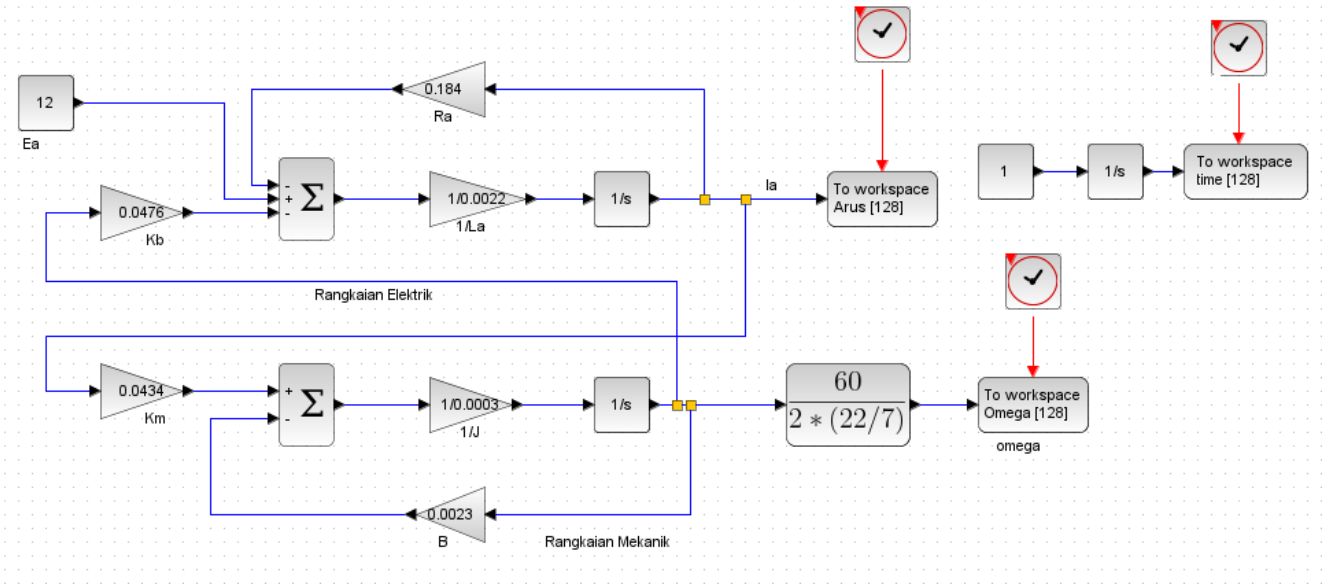
MATA KULIAH : PEMODELAN DAN PENGENDALIAN MESIN LISTRIK
TUGAS III

Nama : Nurqalbi
Stambuk : P2700214051
Program Studi : Teknik Komputer, Kendali, dan Elektronika

Type / Merk Motor DC : PENTA 5XS20

Data	Nilai	Satuan
Daya (P)	100	Watt
	0,13405	HP
Tegangan Jangkar (Ea)	12	Volt
Arus Jangkar (Ia)	11	Ampere
Putaran nominal (ω_{nom})	2000	RPM
	209,44	rad/sec
Momen Inersia (J)	0,0003	$Kg.m^2$
Tahanan jangkar (Ra)	0.184	Ohm
Induktansi Jangkar (La)	$7,5 \times 10^{-3}$	Henry
Efisiensi **(η)**	75,76	%
Konstanta motor (Km)	0,0434	N.m/A
Konstantan GGL lawan (Kb)	0,0476	V.sec/rad
Koefisien gesekan /beban (B)	0,0023	$Kg.m^2$/rad.sec (N.m.sec/rad)
$K_o = Km/J*La$	65767,52	
$2\zeta\omega_n = (B*La+J*Ra)/La*J$	91,23557	
$\omega_n^2 = (B*Ra+Km*Kb)/La*J$	3768,2013	
ω_n	61,3857	



Model Simulasi Motor DC dengan xcos scilab

Pada model ini terdapat 2 masukan berupa beban yang terhubung ke rangkaian mekanik dan Ea(t) yang terhubung ke rangkaian elektrik. Keluaran dari rangkaian elektrik berupa arus jangkar Ia dan keluaran dari rangkaian mekanik adalah kecepatan putar yaitu RPM

Tabel Stability Time & Verifikasi Solusi Analitik dengan Solusi Numerik (xcos scilab) dari $\omega(t)$ dan $I_a(t)$ dengan Relatif Tollerance 10^{-5} , Relatif Tollerance 10^{-9}, dan Relatif Tollerance 10^{-12} berikut :

Relative Tolerance :1e-5

t	ANALITIK			SIMULINK		ERROR ω(t)	ERROR Ia(t)
	ω(t)		Ia(t)	ω(t)	Ia(t)		
	(rad/sec)	(rpm)	(Ampere)	(rpm)	(Ampere)		
0	0	0	0	0	0	0.00%	0.00%
1.00E-02	28.9008479608	275.9827687501	35.119594801	2.76E+02	3.51E+01	0.08%	0.00%
2.00E-02	83.7636958328	799.8843746065	43.4437834556	7.99E+02	43.453696	0.09%	0.02%
3.00E-02	135.9071913338	1297.8180781505	39.0130808224	1.30E+03	39.038627	0.11%	0.07%
4.00E-02	174.4651145539	1666.0191227004	30.5218987856	1.66E+03	30.567158	0.13%	0.15%
5.00E-02	198.328933227	1893.9018048728	22.4346020218	1.89E+03	22.498769	0.14%	0.29%
6.00E-02	210.574182645	2010.8353233292	16.4472066087	2.01E+03	16.525356	0.14%	0.48%
7.00E-02	215.2197279191	2055.197012953	12.737658994	2.05E+03	12.823664	0.14%	0.68%
8.00E-02	215.700336747	2059.7864891922	10.8316477665	2.06E+03	10.921651	0.14%	0.83%
9.00E-02	214.3932488956	2047.3047196363	10.1065743458	2044.4121	10.198626	0.14%	0.91%
0.1	212.6814402426	2030.9581511109	10.0294655731	2028.1154	10.12137	0.14%	0.92%
0.11	211.2172530531	2016.9761933818	10.2310397789	2014.1832	10.32199	0.14%	0.89%
0.12	210.2033231343	2007.2938758701	10.4962296619	2004.541	10.586126	0.14%	0.86%
0.13	209.613143083	2001.6580715217	10.7234268471	1998.9326	10.812312	0.14%	0.83%
0.14	209.3345379809	1998.997588771	10.8809307583	1996.2713	10.969378	0.14%	0.81%
0.15	209.2478078225	1998.1693767653	10.972709626	1995.4336	11.061238	0.14%	0.81%
0.16	209.2589107316	1998.2754017379	11.0161046722	1995.5376	11.104618	0.14%	0.80%
0.17	209.3066409131	1998.7311913969	11.0296724622	1995.9905	11.11831	0.14%	0.80%
0.18	209.3576436531	1999.2182316875	11.0280114764	1996.4769	11.116701	0.14%	0.80%
0.19	209.3977403592	1999.6011270265	11.0206329337	1996.8585	11.109408	0.14%	0.81%
0.2	209.4238503109	1999.8504586988	11.0127262442	1997.0967	11.10174	0.14%	0.81%
0.21	209.4380875771	1999.9864145767	11.0065019001	1997.2349	11.095659	0.14%	0.81%
0.22	209.4441458062	2000.0442664032	11.0024444955	1997.2983	11.091577	0.14%	0.81%
0.23	209.445467974	2000.0568921756	11.0002294354	1997.3159	11.089272	0.14%	0.81%
0.24	209.4445714576	2000.0483310741	10.9992849454	1997.3116	11.088191	0.14%	0.81%
0.25	209.442998773	2000.0333130423	10.9990769864	1997.2995	11.087853	0.14%	0.81%
0.26	209.4415313688	2000.0193003644	10.9992146282	1997.2871	11.087885	0.14%	0.81%
0.27	209.4404578317	2000.0090488407	10.9994580765	1997.2776	11.088054	0.14%	0.81%
0.28	209.4397996814	2000.0027639679	10.9996856842	1997.2714	11.088233	0.14%	0.80%
0.29	209.4394660332	1999.9995778622	10.9998523961	1997.2676	11.088379	0.14%	0.80%
0.3	209.4393426394	1999.998399539	10.9999547096	1997.2655	11.088484	0.14%	0.80%
0.31	209.4393332441	1999.9983098206	11.0000066479	1997.2645	11.088553	0.14%	0.80%
0.32	209.4393718791	1999.9986787575	11.0000259123	1997.2643	11.088593	0.14%	0.81%
0.33	209.439420545	1999.9991434828	11.0000274399	1997.2643	11.088613	0.14%	0.81%
0.34	209.4394615788	1999.9995353267	11.0000214787	1997.2645	11.088622	0.14%	0.81%
0.35	209.4394897161	1999.9998040177	11.0000139386	1997.2646	11.088624	0.14%	0.81%
0.36	209.4395059327	1999.999958875	11.000007571	1997.2648	11.088622	0.14%	0.81%
0.37	209.4395134768	2000.0000309157	11.0000031999	1997.2649	11.08862	0.14%	0.81%
0.38	209.4395157306	2000.0000524382	11.0000006779	1997.265	11.088618	0.14%	0.81%
0.39	209.43951532	2000.000048517	10.9999995027	1997.2651	11.088616	0.14%	0.81%
0.4	209.4395139378	2000.0000353177	10.9999991499	1997.2651	11.088614	0.14%	0.81%
0.41	209.4395124966	2000.0000215551	10.9999992119	1997.2651	11.088613	0.14%	0.81%
0.42	209.439511377	2000.0000108637	10.9999994256	1997.2651	11.088613	0.14%	0.81%
0.43	209.4395106548	2000.0000039674	10.9999996491	1997.2651	11.088613	0.14%	0.81%
0.44	209.4395102652	2000.0000002474	10.9999998229	1997.2651	11.088612	0.14%	0.81%
0.45	209.4395101026	1999.9999986943	10.9999999351	1997.2651	11.088612	0.14%	0.81%
0.46	209.43951007	1999.9999983834	10.9999999957	1997.2651	11.088612	0.14%	0.81%
0.47	209.4395100975	1999.9999986459	11.0000000211	1997.2651	11.088612	0.14%	0.81%
0.48	209.4395101425	1999.9999990758	11.0000000262	1997.2651	11.088612	0.14%	0.81%
0.49	209.4395101838	1999.9999994698	11.000000022	1997.2651	11.088612	0.14%	0.81%

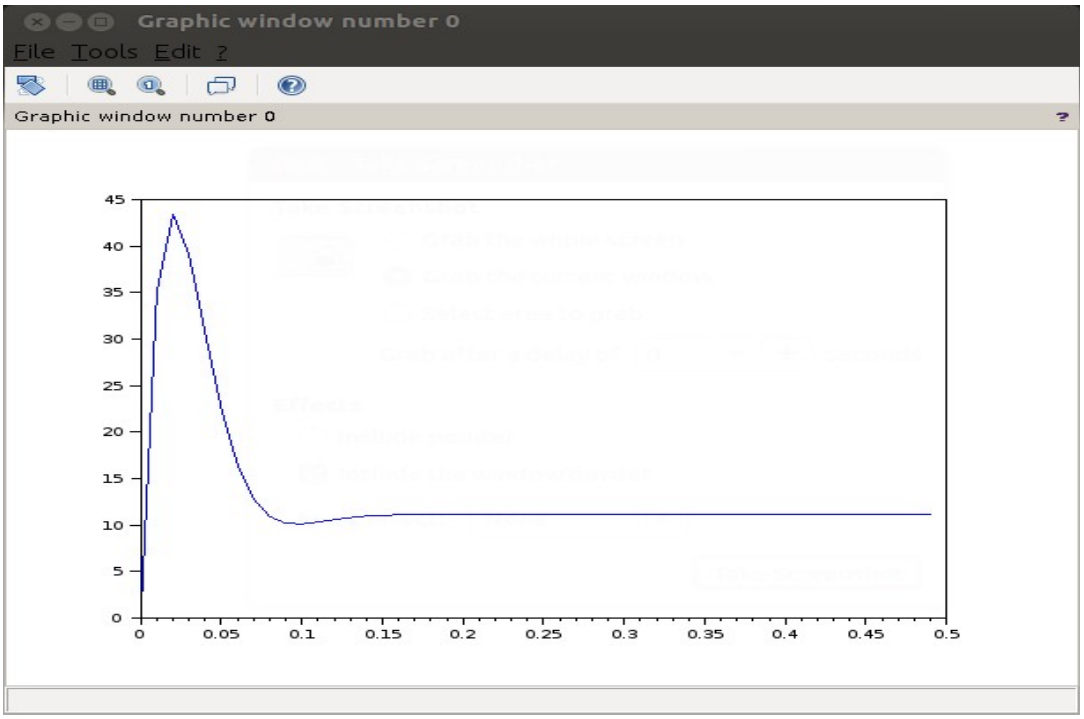
Relative Tolerance :1e-9

t	ANALITIK			SIMULINK		ERROR ω(t)	ERROR Ia(t)
	ω(t)		Ia(t)	ω(t)	Ia(t)		
	(rad/sec)	(rpm)	(Ampere)	(rpm)	(Ampere)		
0	0	0	0	0	0	0.00%	0.00%
1.00E-02	2.89E+01	275.9827687501	35.119594801	2.76E+02	3.51E+01	0.08%	0.01%
2.00E-02	83.7636958328	799.8843746065	43.4437834556	7.99E+02	43.454716	0.10%	0.03%
3.00E-02	135.9071913338	1297.8180781505	39.0130808224	1.30E+03	39.040126	0.11%	0.07%
4.00E-02	174.4651145539	1666.0191227004	30.5218987856	1.66E+03	30.56799	0.13%	0.15%
5.00E-02	198.328933227	1893.9018048728	22.4346020218	1.89E+03	22.498475	0.14%	0.28%
6.00E-02	210.574182645	2010.8353233292	16.4472066087	2.01E+03	16.524957	0.14%	0.47%
7.00E-02	215.2197279191	2055.197012953	12.737658994	2.05E+03	12.824547	0.14%	0.68%
8.00E-02	215.700336747	2059.7864891922	10.8316477665	2.06E+03	10.923411	0.14%	0.85%
9.00E-02	214.3932488956	2047.3047196363	10.1065743458	2044.3761	10.200075	0.14%	0.93%
0.1	212.6814402426	2030.9581511109	10.0294655731	2028.0909	10.122796	0.14%	0.93%
0.11	211.2172530531	2016.9761933818	10.2310397789	2014.166	10.323309	0.14%	0.90%
0.12	210.2033231343	2007.2938758701	10.4962296619	2004.5264	10.587234	0.14%	0.87%
0.13	209.613143083	2001.6580715217	10.7234268471	1998.9173	10.813339	0.14%	0.84%
0.14	209.3345379809	1998.997588771	10.8809307583	1996.2702	10.970065	0.14%	0.82%
0.15	209.2478078225	1998.1693767653	10.972709626	1995.4465	11.061379	0.14%	0.81%
0.16	209.2589107316	1998.2754017379	11.0161046722	1995.5518	11.104552	0.14%	0.80%
0.17	209.3066409131	1998.7311913969	11.0296724622	1996.0048	11.118056	0.14%	0.80%
0.18	209.3576436531	1999.2182316875	11.0280114764	1996.4887	11.116418	0.14%	0.80%
0.19	209.3977403592	1999.6011270265	11.0206329337	1996.869	11.109094	0.14%	0.80%
0.2	209.4238503109	1999.8504586988	11.0127262442	1997.1166	11.101246	0.14%	0.80%
0.21	209.4380875771	1999.9864145767	11.0065019001	1997.2515	11.095067	0.14%	0.80%
0.22	209.4441458062	2000.0442664032	11.0024444955	1997.309	11.091041	0.14%	0.81%
0.23	209.445467974	2000.0568921756	11.0002294354	1997.3215	11.088843	0.14%	0.81%
0.24	209.4445714576	2000.0483310741	10.9992849454	1997.313	11.087905	0.14%	0.81%
0.25	209.442998773	2000.0333130423	10.9990769864	1997.2981	11.087699	0.14%	0.81%
0.26	209.4415313688	2000.0193003644	10.9992146282	1997.2842	11.087835	0.14%	0.81%
0.27	209.4404578317	2000.0090488407	10.9994580765	1997.2741	11.088076	0.14%	0.81%
0.28	209.4397996814	2000.0027639679	10.9996856842	1997.2678	11.088301	0.14%	0.81%
0.29	209.4394660332	1999.9995778622	10.9998523961	1997.2647	11.088466	0.14%	0.81%
0.3	209.4393426394	1999.998399539	10.9999547096	1997.2635	11.088568	0.14%	0.81%
0.31	209.4393332441	1999.9983098206	11.0000066479	1997.2634	11.088619	0.14%	0.81%
0.32	209.4393718791	1999.9986787575	11.0000259123	1997.2638	11.088638	0.14%	0.81%
0.33	209.439420545	1999.9991434828	11.0000274399	1997.2643	11.08864	0.14%	0.81%
0.34	209.4394615788	1999.9995353267	11.0000214787	1997.2646	11.088634	0.14%	0.81%
0.35	209.4394897161	1999.9998040177	11.0000139386	1997.2649	11.088626	0.14%	0.81%
0.36	209.4395059327	1999.999958875	11.000007571	1997.2651	11.08862	0.14%	0.81%
0.37	209.4395134768	2000.0000309157	11.0000031999	1997.2651	11.088616	0.14%	0.81%
0.38	209.4395157306	2000.0000524382	11.0000006779	1997.2652	11.088613	0.14%	0.81%
0.39	209.43951532	2000.000048517	10.9999995027	1997.2651	11.088612	0.14%	0.81%
0.4	209.4395139378	2000.0000353177	10.9999991499	1997.2651	11.088612	0.14%	0.81%
0.41	209.4395124966	2000.0000215551	10.9999992119	1997.2651	11.088612	0.14%	0.81%
0.42	209.439511377	2000.0000108637	10.9999994256	1997.2651	11.088612	0.14%	0.81%
0.43	209.4395106548	2000.0000039674	10.9999996491	1997.2651	11.088612	0.14%	0.81%
0.44	209.4395102652	2000.0000002474	10.9999998229	1997.2651	11.088612	0.14%	0.81%
0.45	209.4395101026	1999.9999986943	10.9999999351	1997.2651	11.088612	0.14%	0.81%
0.46	209.43951007	1999.9999983834	10.9999999957	1997.2651	11.088612	0.14%	0.81%
0.47	209.4395100975	1999.9999986459	11.0000000211	1997.2651	11.088612	0.14%	0.81%
0.48	209.4395101425	1999.9999990758	11.0000000262	1997.2651	11.088612	0.14%	0.81%
0.49	209.4395101838	1999.9999994698	11.000000022	1997.2651	11.088612	0.14%	0.81%

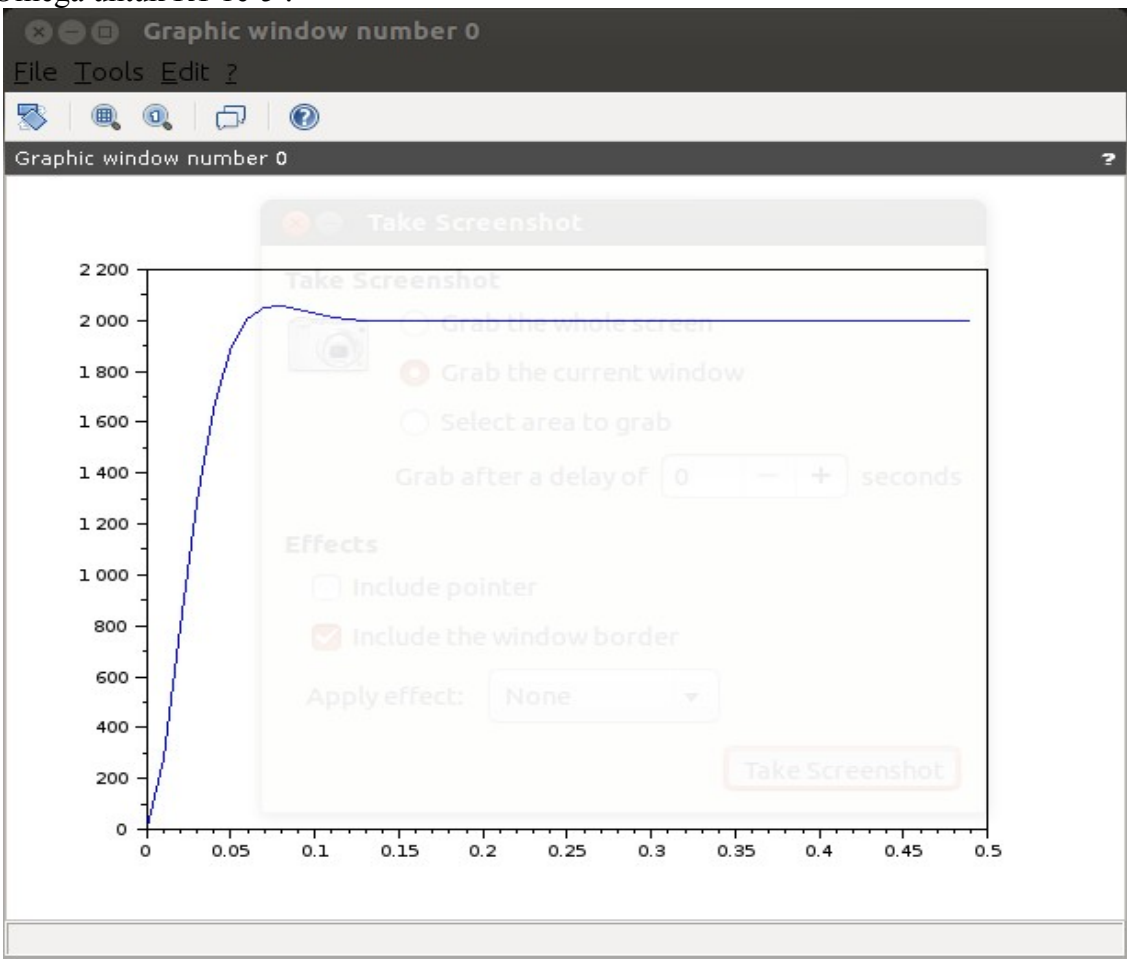
Relative Tolerance :1e-12

t	ANALITIK			SIMULINK		ERROR ω(t)	ERROR Ia(t)
	ω(t)		Ia(t)	ω(t)	Ia(t)		
	(rad/sec)	(rpm)	(Ampere)	(rpm)	(Ampere)		
0	0	0	0	0	0	0.00%	0.00%
1.00E-02	2.89E+01	275.9827687502	35.119594801	2.76E+02	35.121412	0.08%	100.00%
2.00E-02	83.7636958328	799.8843746065	43.4437834556	7.99E+02	43.454716	0.10%	19.16%
3.00E-02	135.9071913338	1297.8180781505	39.0130808224	1.30E+03	39.040126	0.11%	11.38%
4.00E-02	174.4651145539	1666.0191227004	30.5218987856	1.66E+03	30.567989	0.13%	27.91%
5.00E-02	198.328933227	1893.9018048728	22.4346020218	1.89E+03	22.498474	0.14%	36.25%
6.00E-02	210.574182645	2010.8353233292	16.4472066087	2.01E+03	16.524956	0.14%	36.79%
7.00E-02	215.2197279191	2055.197012953	12.737658994	2.05E+03	12.824546	0.14%	29.73%
8.00E-02	215.700336747	2059.7864891922	10.8316477665	2.06E+03	10.923411	0.14%	18.40%
9.00E-02	214.3932488956	2047.3047196363	10.1065743458	2044.3761	10.200075	0.14%	8.08%
0.1	212.6814402426	2030.9581511109	10.0294655731	2028.0909	10.122796	0.14%	1.70%
0.11	211.2172530531	2016.9761933818	10.2310397789	2014.166	10.323309	0.14%	1.06%
0.12	210.2033231343	2007.2938758701	10.4962296619	2004.5264	10.587234	0.14%	1.65%
0.13	209.613143083	2001.6580715217	10.7234268471	1998.9173	10.81334	0.14%	1.27%
0.14	209.3345379809	1998.997588771	10.8809307583	1996.2702	10.970066	0.14%	0.62%
0.15	209.2478078225	1998.1693767653	10.972709626	1995.4465	11.061379	0.14%	0.02%
0.16	209.2589107316	1998.2754017379	11.0161046722	1995.5518	11.104552	0.14%	0.41%
0.17	209.3066409131	1998.7311913969	11.0296724622	1996.0048	11.118056	0.14%	0.68%
0.18	209.3576436531	1999.2182316875	11.0280114764	1996.4887	11.116418	0.14%	0.82%
0.19	209.3977403592	1999.6011270265	11.0206329337	1996.869	11.109094	0.14%	0.87%
0.2	209.4238503109	1999.8504586988	11.0127262442	1997.1166	11.101246	0.14%	0.88%
0.21	209.4380875771	1999.9864145767	11.0065019001	1997.2515	11.095068	0.14%	0.86%
0.22	209.4441458062	2000.0442664032	11.0024444955	1997.309	11.091041	0.14%	0.84%
0.23	209.445467974	2000.0568921756	11.0002294354	1997.3215	11.088843	0.14%	0.83%
0.24	209.4445714576	2000.0483310741	10.9992849454	1997.313	11.087905	0.14%	0.81%
0.25	209.442998773	2000.0333130423	10.9990769864	1997.2981	11.087699	0.14%	0.81%
0.26	209.4415313688	2000.0193003644	10.9992146282	1997.2842	11.087835	0.14%	0.80%
0.27	209.4404578317	2000.0090488407	10.9994580765	1997.2741	11.088076	0.14%	0.80%
0.28	209.4397996814	2000.0027639679	10.9996856842	1997.2678	11.088301	0.14%	0.80%
0.29	209.4394660332	1999.9995778622	10.9998523961	1997.2647	11.088466	0.14%	0.80%
0.3	209.4393426394	1999.998399539	10.9999547096	1997.2635	11.088568	0.14%	0.80%
0.31	209.4393332441	1999.9983098206	11.0000066479	1997.2634	11.088619	0.14%	0.81%
0.32	209.4393718791	1999.9986787575	11.0000259123	1997.2638	11.088638	0.14%	0.81%
0.33	209.439420545	1999.9991434828	11.0000274399	1997.2643	11.08864	0.14%	0.81%
0.34	209.4394615788	1999.9995353267	11.0000214787	1997.2646	11.088634	0.14%	0.81%
0.35	209.4394897161	1999.9998040177	11.0000139386	1997.2649	11.088626	0.14%	0.81%
0.36	209.4395059327	1999.999958875	11.000007571	1997.2651	11.08862	0.14%	0.81%
0.37	209.4395134768	2000.0000309157	11.0000031999	1997.2651	11.088616	0.14%	0.81%
0.38	209.4395157306	2000.0000524382	11.0000006779	1997.2652	11.088613	0.14%	0.81%
0.39	209.43951532	2000.000048517	10.9999995027	1997.2651	11.088612	0.14%	0.81%
0.4	209.4395139378	2000.0000353177	10.9999991499	1997.2651	11.088612	0.14%	0.81%
0.41	209.4395124966	2000.0000215551	10.9999992119	1997.2651	11.088612	0.14%	0.81%
0.42	209.439511377	2000.0000108637	10.9999994256	1997.2651	11.088612	0.14%	0.81%
0.43	209.4395106548	2000.0000039674	10.9999996491	1997.2651	11.088612	0.14%	0.81%
0.44	209.4395102652	2000.0000002474	10.9999998229	1997.2651	11.088612	0.14%	0.81%
0.45	209.4395101026	1999.9999986943	10.9999999351	1997.2651	11.088612	0.14%	0.81%
0.46	209.43951007	1999.9999983834	10.9999999957	1997.2651	11.088612	0.14%	0.81%
0.47	209.4395100975	1999.9999986459	11.0000000211	1997.2651	11.088612	0.14%	0.81%
0.48	209.4395101425	1999.9999990758	11.0000000262	1997.2651	11.088613	0.14%	0.81%
0.49	209.4395101838	1999.9999994698	11.000000022	1997.2651	11.088612	0.14%	0.81%

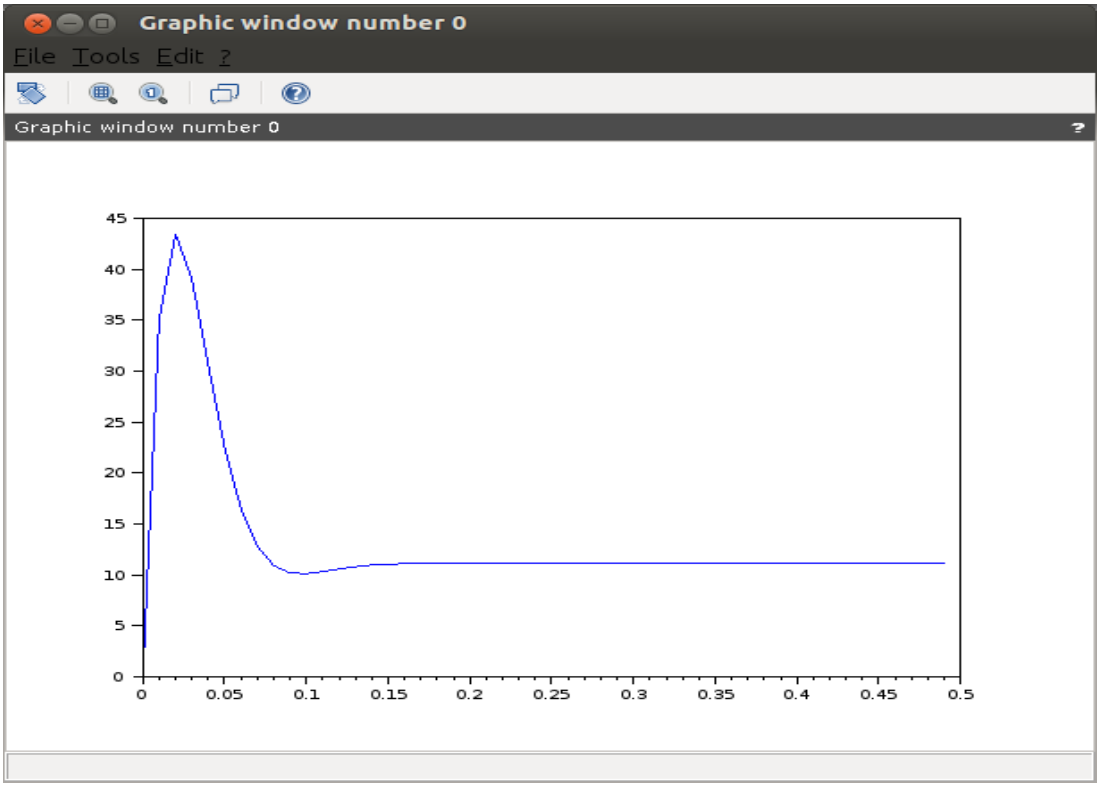
Gambar Grafik Arus dan Omega pada xcos Scilab :
*Grafik Arus untuk Relatif Tolerance 1e-5 :



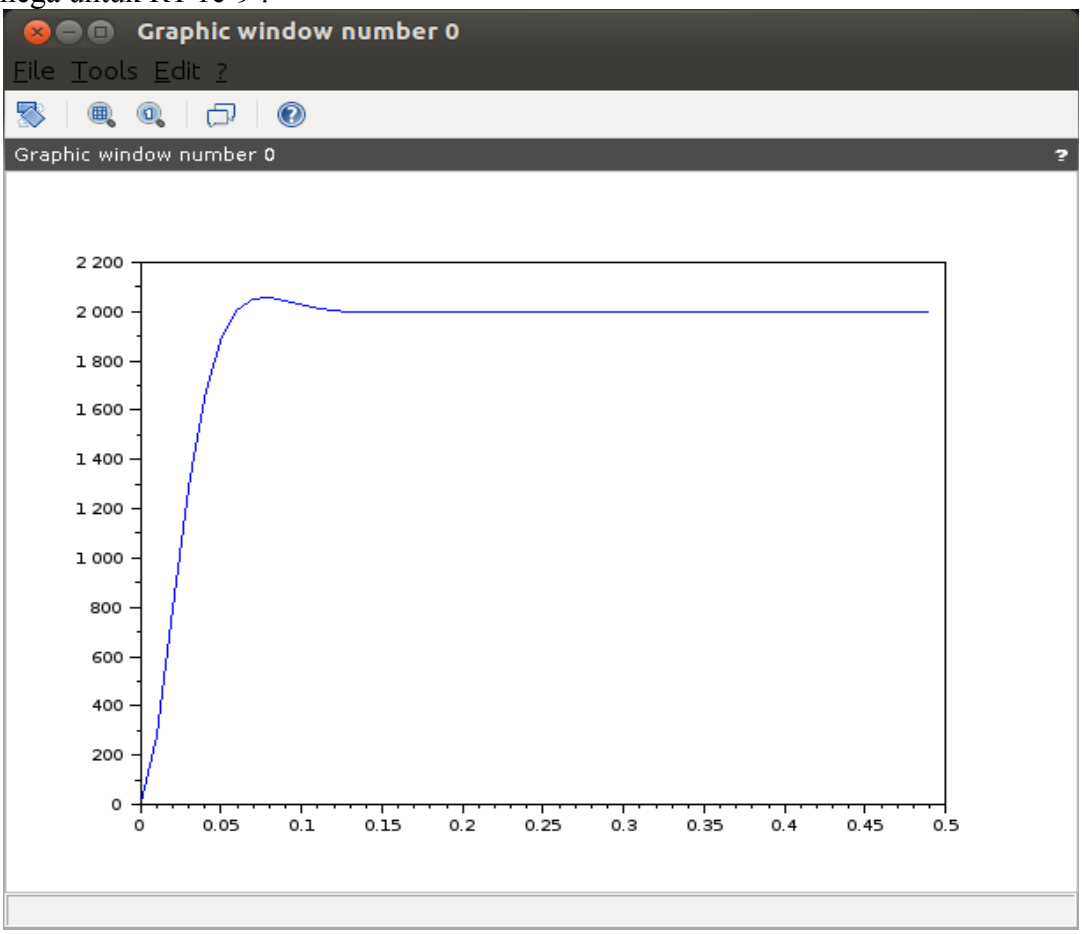
Grafik Omega untuk RT 1e-5 :



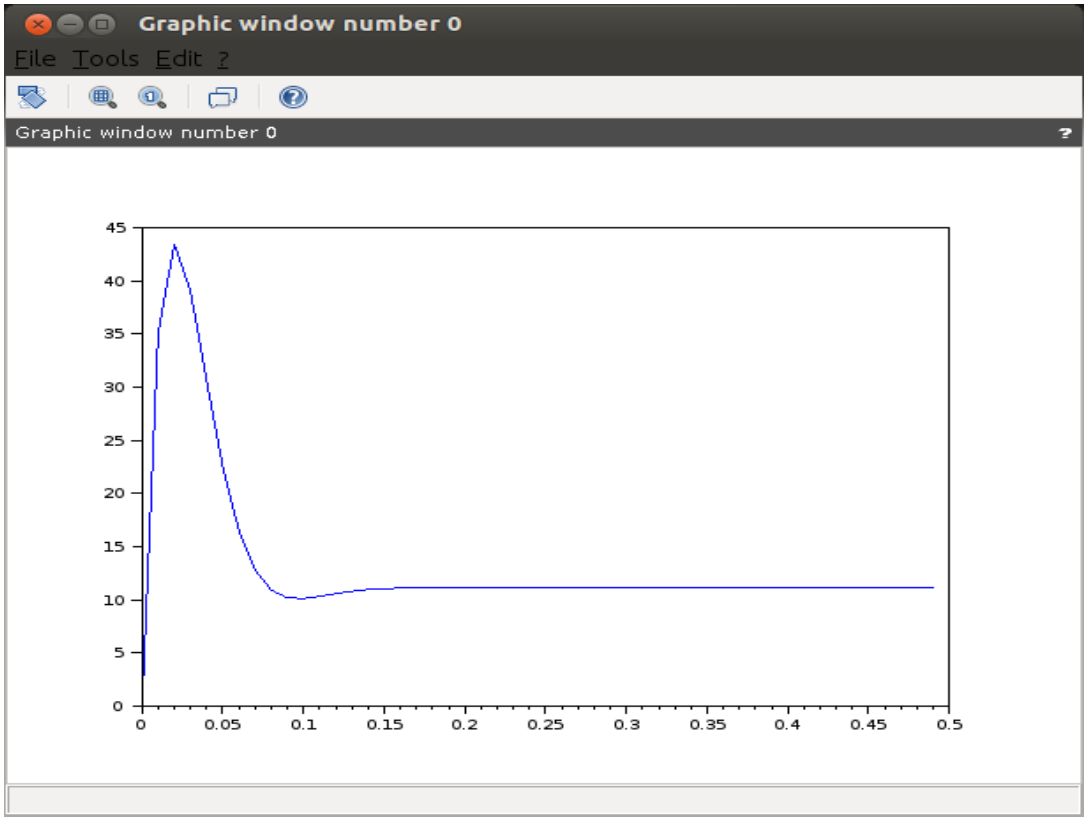
*Grafik Arus untuk RT 1e-9 :



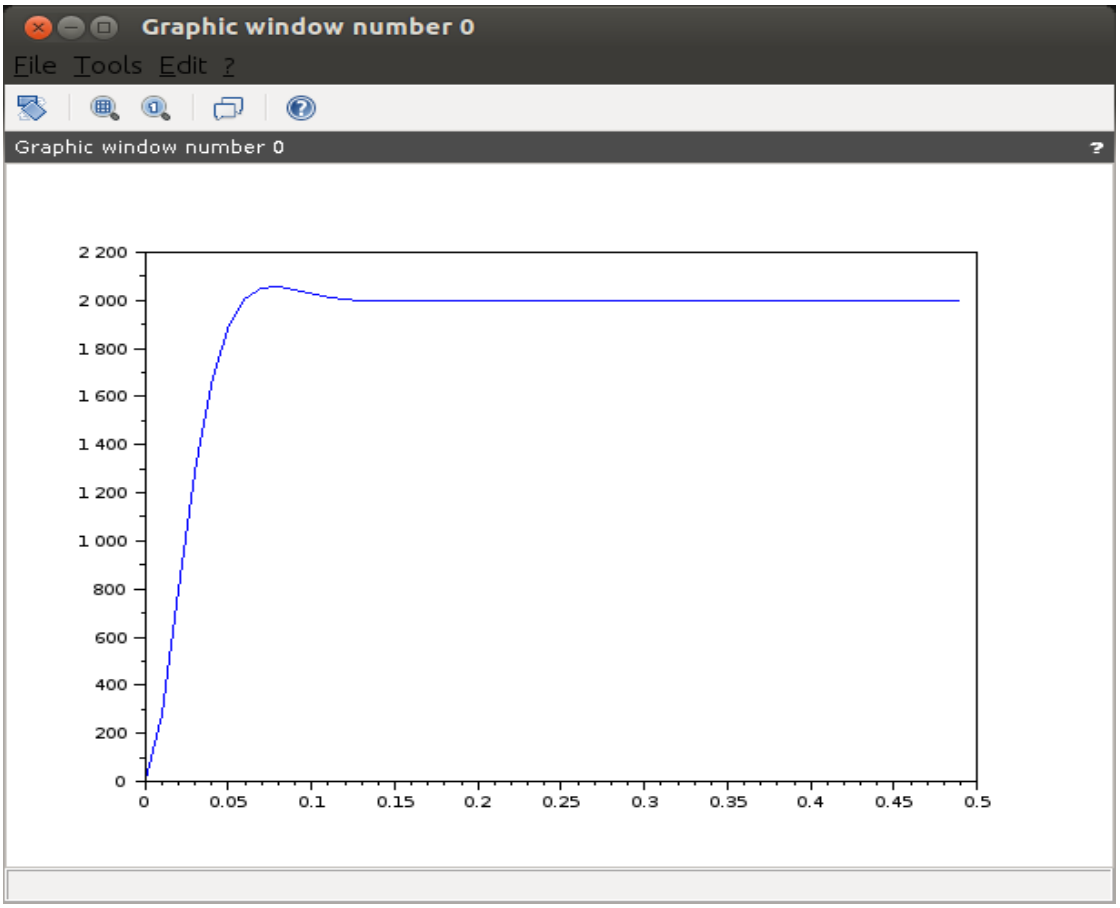
Grafik Omega untuk RT 1e-9 :

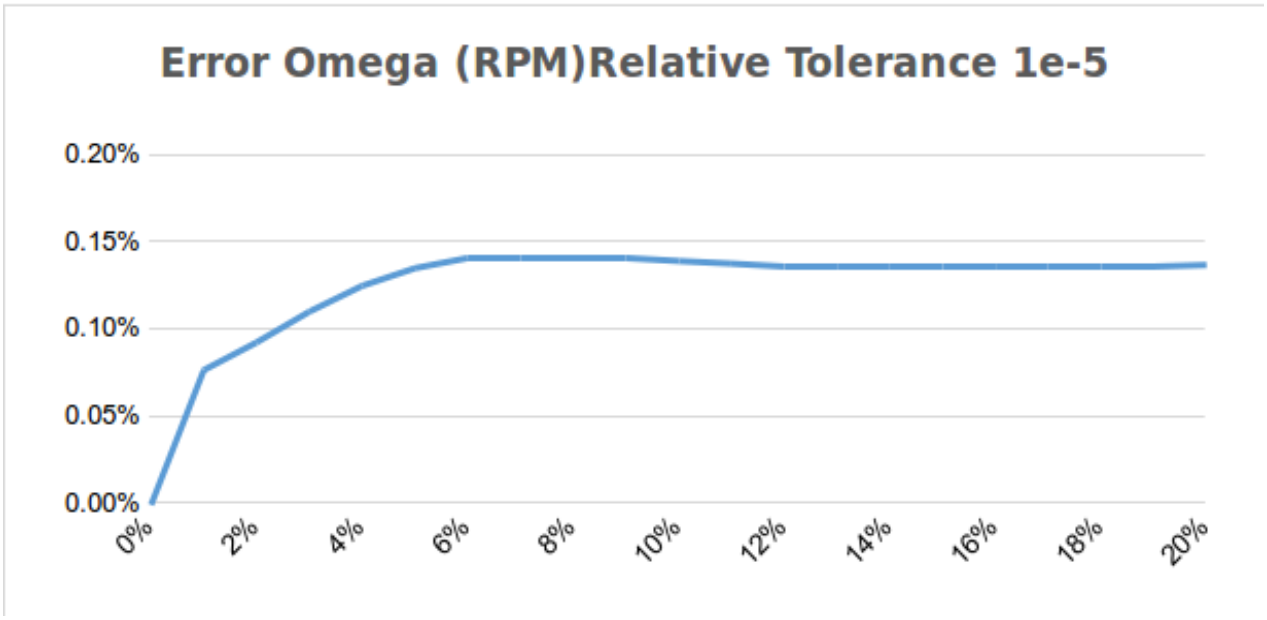


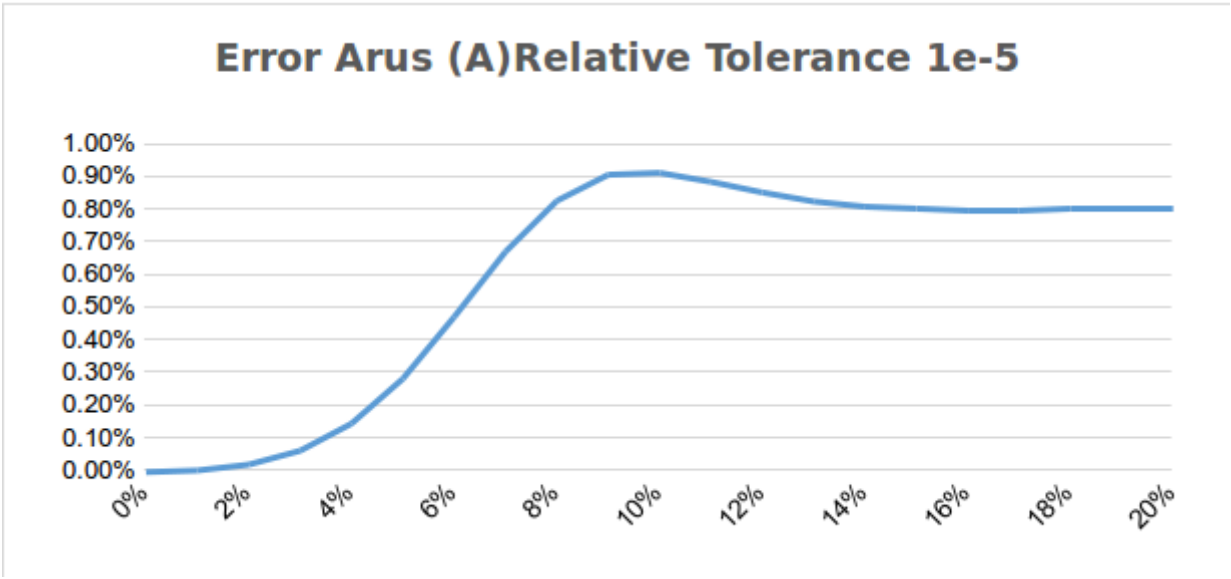
Grafik Arus untuk RT 1e-12 :

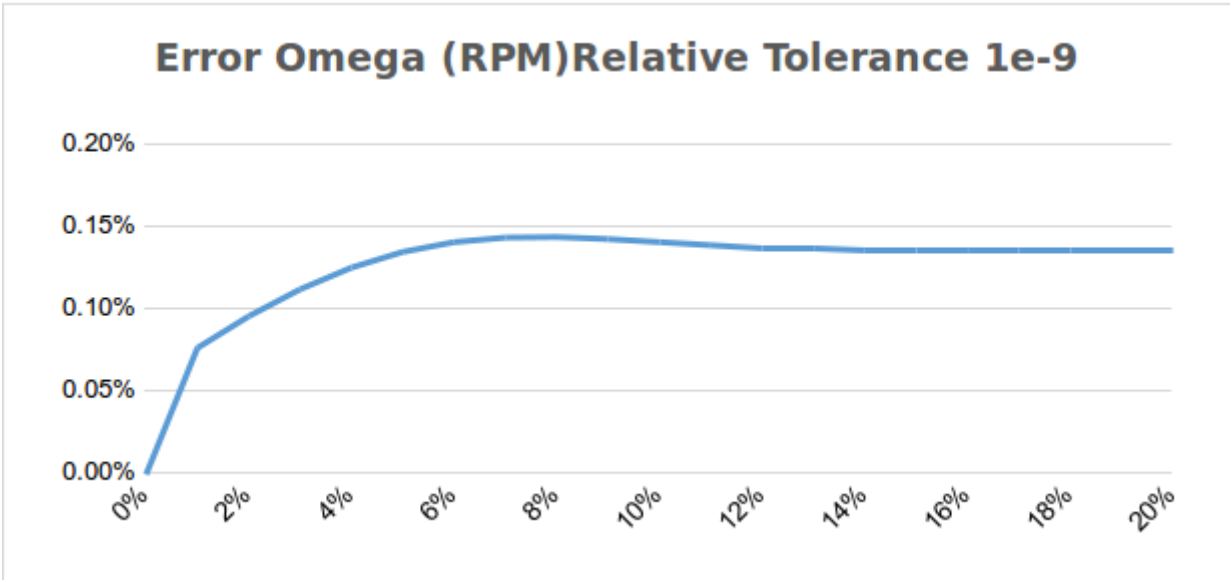


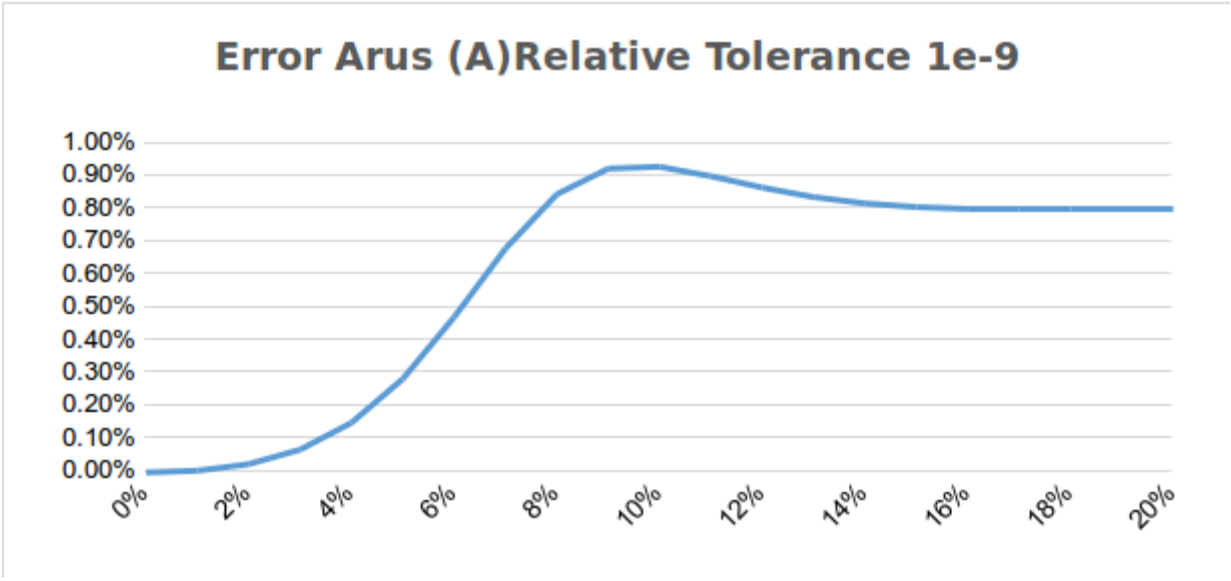
Grafik Omega untuk RT 1e-12 :




Error Omega (RPM)Relative Tolerance 1e-5
0.20%
0.15%
0.10%
0.05%
0.00%
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%


Error Arus (A)Relative Tolerance 1e-5
1.00%
0.90%
0.80%
0.70%
0.60%
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%


Error Omega (RPM)Relative Tolerance 1e-9
0.20%
0.15%
0.10%
0.05%
0.00%
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%


Error Arus (A)Relative Tolerance 1e-9
1.00%
0.90%
0.80%
0.70%
0.60%
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
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2%
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16%
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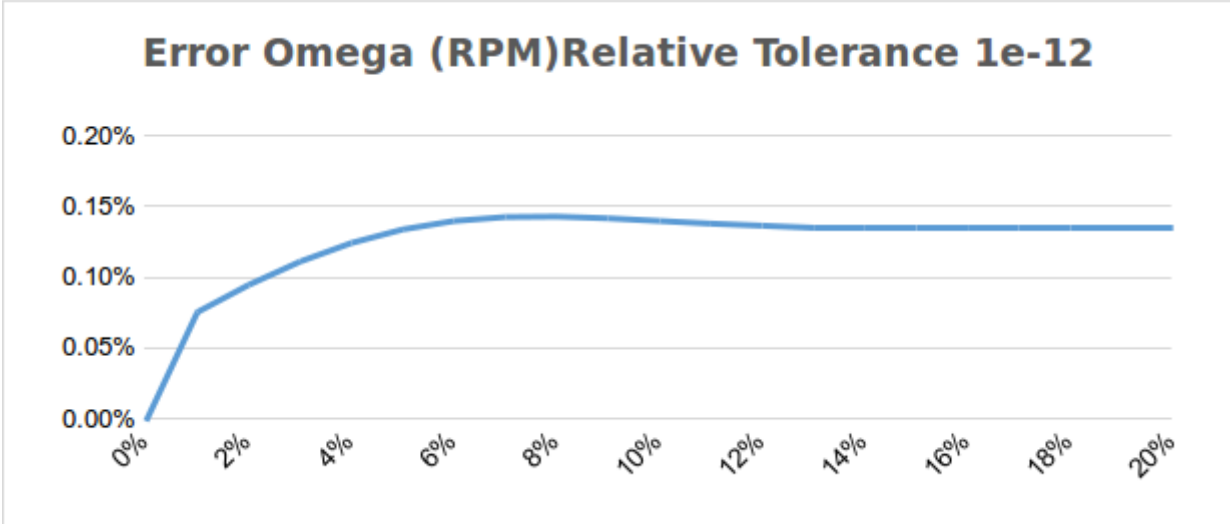
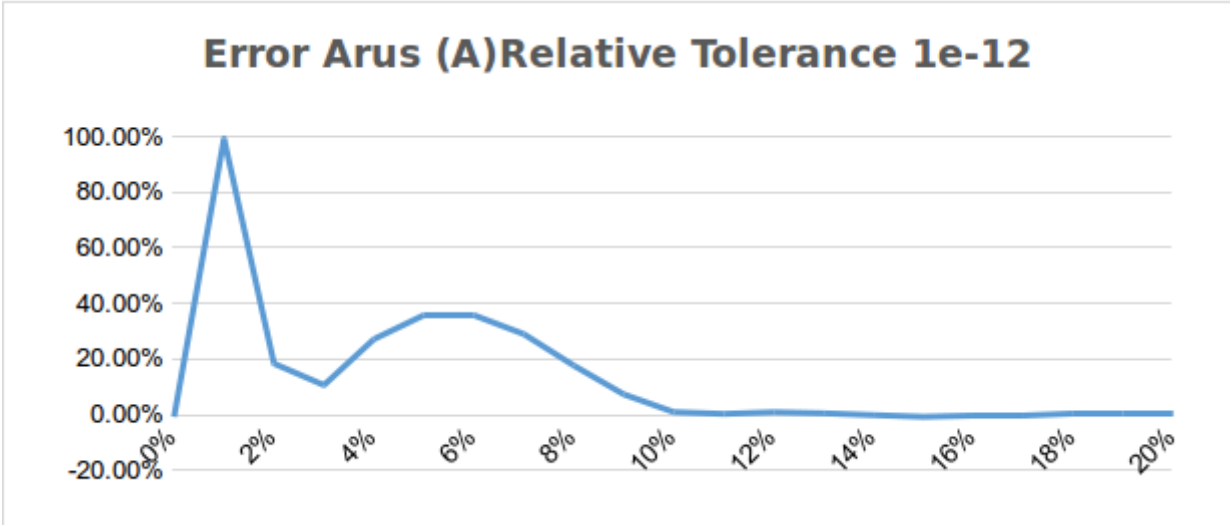
20%


Error Omega (RPM)Relative Tolerance 1e-12
0.20%
0.15%
0.10%
0.05%
0.00%
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%



Kesimpulan

Berdasarkan hasil verifikasi antara analitik dan xcos pada kecepatan motor w(t) dan arus jangkar Ia(t), sistem relatif stabil karena error yang terjadi :

untuk Relative Tollerance 1e-5 : error pada Omega : 0,08% - 0,14%
error pada arus : 0,02% - 0,81%

Untuk Relative Tollerance 1e-9 : error pada Omega : 0,08% - 0,14%
error pada Arus : 0,01% - 0,81%

Untuk Relative Tollerance 1e-12 : error pada Omega : 0,08% - 0,14%

* untuk arus pada saat t = 0,02 s, terjadi error sebesar 100%.
dan pada saat t = 0,03 s – 0,09 s, arusnya tidak stabil karena error yang terjadi :

Waktu (t)	Error (%)
0,03 s	19,16
0,04 s	11,13
0,05 s	27,91
0,06 s	36,79
0,07 s	29,73
0,08 s	18,40
0,09 s	8

Sedangkan pada saat t = 0,1 s – 0,49 s % , diperoleh nilai arus yang relatif stabil karena error yang terjadi sekitar : 1,7 – 0,81 %.

Dan saat t = 0,37 s , secara analitik diperoleh Omega = 2000 RPM dan Arus = 11 A untuk Relative Tollerance 1e-5, 1e-9 dan 1e-12. Sedangkan secara xcos (simulink) diperoleh Omega = 1997,2651 dan Arus = 11,088616 untuk Relative Tollerance 1e-9 dan 1e-12. Tetapi untuk Relative Tollerance 1e-5, diperoleh Omega = 1997,2649 dan Arus = 11,08862.