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IEEE 34 Node test system as Simulation Test Bench for Load Flow Analysis in EMTP RV

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Abstract—***The IEEE Power Engineering Society Distribution Subcommittee published five benchmark distribution feeders with their configurations and parameters. Amongst these feeders, the IEEE 34 node distribution test feeder was selected. Load flow or Power flow studies exhibits its importance for determining sinusoidal steady state of entire system-voltages, real and reactive power generated and line losses. EMTP RV incorporates its significance for load flow, steadystate, time domain and frequency scan simulation enhancing most advanced user defined modelling capabilities. The main objective of this paper is to analyse this test bench in EMTP RV and report its results.***

Keywords— IEEE 34 Node test system, Load flow analysis, EMTP RV

INTRODUCTION

IEEE 34 Node Test Feeder is an existing feeder located in Arizona, with a nominal voltage of 24.9 kV. It is characterized by long and lightly loaded overhead transmission lines, two in-line regulators, one in-line transformer for a short 4.16 kV section, a total number of 24 unbalanced loads, and two shunt capacitors.The IEEE Distribution System Analysis Subcommittee developed and published data for a variety of unbalanced radial distribution test feeders the primary purpose of which is the evaluation of power system analysis software. These test systems are for use by software developers and field engineers for validating their studies. The IEEE 34 Node Test Feeder represents an actual feeder in Arizona and has the following features reflecting the physical world.

1) Each section of the distribution system is modeled by actual phase impedance values.

2) The system includes single and two phase laterals.

3) Loads on each phase of each section are specified in real and reactive power

4) Distributed load models represent load on feeders with closely spaced load taps.

5) The system includes voltage regulators and capacitive reactive power compensation.

6) The system has very long distributions lines and is lightly loaded.

7) There is an in-line transformer for reducing voltage to 4.16 kV for a short section of the feeder.

I. Load Flow Analysis

AC power flow analysis is basically a steady-state analysis of the AC transmission and distribution grid. Essentially, AC power flow method computes the steady state values of bus voltages and line power flows from the knowledge of electric loads and generations at different buses of the system under study.Load flow analysis is the most important and essential approach to investigating problems in power system operating and planning. Based on a specified generating state and transmission network structure, load flow analysis solves the steady operation state with node voltages and branch power flow in the power system. Load flow analysis can provide a balanced steady operation state of the power system, without considering system transient processes. Hence, the mathematic model of load flow problem is

a nonlinear algebraic equation system without differential equations.The purpose of power flow studies is to plan ahead and account for various hypothetical situations. For example, if a transmission line is be taken off line for maintenance, can the remaining lines in the system handle the required loads without exceeding their rated values.

II. EMTP RV Software

An EMTP RV exhibits its significance in terms of solution for large networks. It provides detailed modelling of the network component including control, linear and non-linear elements. It incorporates open architecture coding that allows users customization and implementation of sophisticated mode.It exhibits new steady-state solution with harmonics and new three-phase load-flow.It serves automatic initialization from steady-state solution .It also has new capability for solving detailed semiconductor models and simultaneous switching options for power electronics applications is also applicable.EMTP-RV is suited to a wide variety of power system studies, whether they relate to project design and engineering, or to solving problems and unexplained failures. EMTP-RV offers a wide variety of modelling capabilities encompassing electromagnetic and electromechanical oscillations ranging in duration from microseconds to seconds.EMTP-RV’s benefits are: Unmatched ease of use, Superiormodelling flexibility, Customizable to your needs, Dynamic development road-map, Prompt and effective technical support and Reactive sales teams.EMTP-RV is suited to a wide variety of power system studies including and not limited to Power system design , Power system stability & load modelling , Control system design , Motor starting , Power electronics and FACTS , HVDC networks , Lighting surges , Switching surges , Temporary overvoltage’s , Insulation coordination , Complete network analysis , Ferro resonance , Steady-state analysis of unbalanced system , Distribution networks and distributed generation , Power system dynamic and load modelling , Sub synchronous resonance and shaft stresses , Power system protection issues , General control system design , Power quality issues , Capacitor bank switching andmuch more. Its application includes Power system design , Power systems protection issues , Network analysis: network separation, power quality, geomagnetic storms, interaction between compensation and control components, wind generation , Detailed simulation and analysis of large scale (unlimited size) electrical systems , Simulation and analysis of power system transients: lightning, switching, temporary conditions , General purpose circuit analysis: wideband, from load-flow to steady state to time-domain (Steady-state analysis of unbalanced systems) ,Synchronous machines: SSR, auto-excitation, control , Transmission line systems: insulation coordination, switching, design, wideband line and cable models.Power Electronics and FACTS (HVDC, SVC, VSC, TCSC, etc.) , Multi terminal HVDC systems , Series compensation: MOV energy absorption, short-circuit conditions, network interaction , Transmission line systems: insulation coordination, switching, design, wideband line and cable models , Switchgear: TRV, shunt compensation, current chopping, delayed current zero conditions, arc interaction , Protection: power oscillations, saturation problems, surge arrester influences , Temporary over voltages , Capacitor bank switching , Series and shunt resonances , Detailed transient stability analysis and Unbalanced distribution networks.

A. Load flow analysis in EMTP RV

The electrical network equations are solved using complex phasors. The active (source) devices are only the Load-Flow devices (LF-devices). A load device is used to enter PQ load constraint equations. Only single (fundamental) frequency solutions are achievable in this version. The solution frequency is specified by ‘Default Power Frequency’ and used in passive network lumped model calculations. The same network used for transient simulations can be used in load flow analysis. The EMTP Load-Flow solution can work with multiphase and unbalanced networks. The control system devices are disconnected and not solved. This simulation option stops and creates a solution file (Load-Flow solution data file). The solution file can be loaded for automatically initializing anyone of the following solution methods.

TEST SYSTEM AND DATA

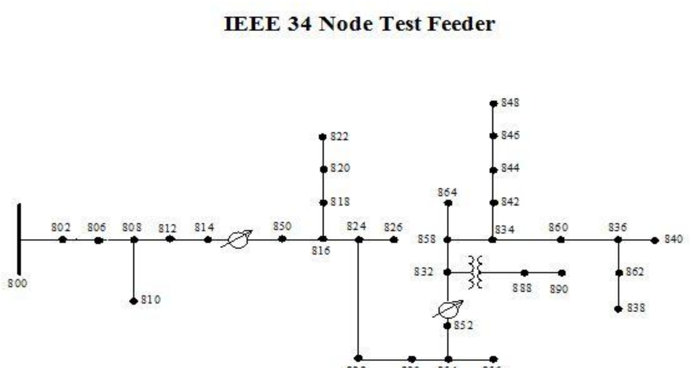


Fig. 1Schematic Diagram of IEEE 34 Node Test Feeder

Transformer Data					
	kVA	kV-high	kV-low	R - %	X - %
Substation:	2500	69 - D	24.9 -Gr. W	1	8
XFM -1	500	24.9 Gr.W	4.16 Gr. W	1.9	4.08

Shunt Capacitors			
	Ph-A	Ph-B	Ph-C
Node	kVAr	kVAr	kVAr
844	100	100	100
848	150	150	150
Total	250	250	250

Spot Loads							
Node	Load	Ph-1	Ph-1	Ph-2	Ph-2	Ph-3	Ph-4
	Model	kW	kVAr	kW	kVAr	kW	kVAr
860	Y-PQ	20	16	20	16	20	16
840	Y-I	9	7	9	7	9	7
844	Y-Z	135	105	135	105	135	105
848	D-PQ	20	16	20	16	20	16
890	D-I	150	75	150	75	150	75
830	D-Z	10	5	10	5	25	10
Total		344	224	344	224	359	229

Distributed Loads								
Node	Node	Load	Ph-1	Ph-1	Ph-2	Ph-2	Ph-3	Ph-3
A	B	Model	kW	kVAr	kW	kVAr	kW	kVAr
802	806	Y-PQ	0	0	30	15	25	14
808	810	Y-I	0	0	16	8	0	0
818	820	Y-Z	34	17	0	0	0	0
820	822	Y-PQ	135	70	0	0	0	0
816	824	D-I	0	0	5	2	0	0
824	826	Y-I	0	0	40	20	0	0
824	828	Y-PQ	0	0	0	0	4	2
828	830	Y-PQ	7	3	0	0	0	0
854	856	Y-PQ	0	0	4	2	0	0
832	858	D-Z	7	3	2	1	6	3
858	864	Y-PQ	2	1	0	0	0	0
858	834	D-PQ	4	2	15	8	13	7
834	860	D-Z	16	8	20	10	110	55
860	836	D-PQ	30	15	10	6	42	22
836	840	D-I	18	9	22	11	0	0
862	838	Y-PQ	0	0	28	14	0	0
842	844	Y-PQ	9	5	0	0	0	0
844	846	Y-PQ	0	0	25	12	20	11
846	848	Y-PQ	0	0	23	11	0	0
Total			262	133	240	120	220	114

Regulator Data			
Regulator ID:	1		
Line Segment:	814 -850		
Location:	814		
Phases:	A - B -C		
Connection:	3-Ph,LG		
Monitoring Phase:	A-B-C		
Bandwidth:	2.0 volts		
PT Ratio:	120		
Primary CT Rating:	100		
Compensator Settings:	Ph-A	Ph-B	Ph-C
R - Setting:	2.7	2.7	2.7
X - Setting:	1.6	1.6	1.6
Volltage Level:	122	122	122
Regulator ID:	2		
Line Segment:	852 -832		
Location:	852		
Phases:	A - B -C		
Connection:	3-Ph,LG		
Monitoring Phase:	A-B-C		
Bandwidth:	2.0 volts		
PT Ratio:	120		
Primary CT Rating:	100		
Compensator Settings:	Ph-A	Ph-B	Ph-C
R - Setting:	2.5	2.5	2.5
X - Setting:	1.5	1.5	1.5
Volltage Level:	124	124	124

Overhead Line Configurations (Config.)				
Config.	Phasing	Phase	Neutral	Spacing ID
		ACSR	ACSR	
300	B A C N	1/0	1/0	500
301	B A C N	#2 6/1	#2 6/1	500
302	A N	#4 6/1	#4 6/1	510
303	B N	#4 6/1	#4 6/1	510
304	B N	#2 6/1	#2 6/1	510

Line Segment Data			
Node A	Node B	Length(ft.)	Config.
800	802	2580	300
802	806	1730	300
806	808	32230	300
808	810	5804	303
808	812	37500	300
812	814	29730	300
814	850	10	301
816	818	1710	302
816	824	10210	301
818	820	48150	302
820	822	13740	302
824	826	3030	303
824	828	840	301
828	830	20440	301
830	854	520	301
832	858	4900	301
832	888	0	XFM-1
834	860	2020	301
834	842	280	301
836	840	860	301
836	862	280	301
842	844	1350	301
844	846	3640	301
846	848	530	301
850	816	310	301
852	832	10	301
854	856	23330	303
854	852	36830	301
858	864	1620	303
858	834	5830	301
860	836	2680	301
862	838	4860	304
888	890	10560	300

RESULTS

A. Node Voltages

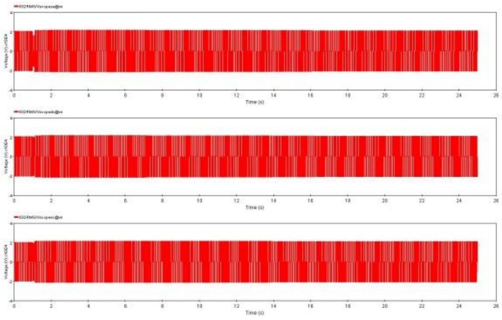


Fig.1 832 RMS/Vscopesa@vn, RMS/Vscopesb@vn RMS/Vscopesc@vn

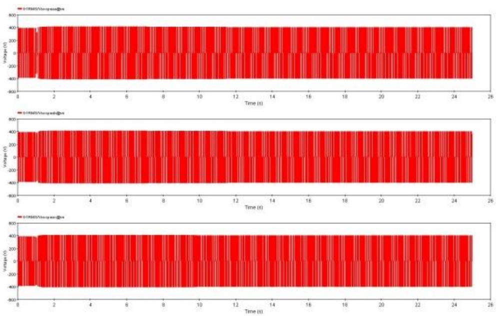


Fig.2 G1/Vscopesa@vn, G1/Vscopesb@vn G1/Vscopesc@vn

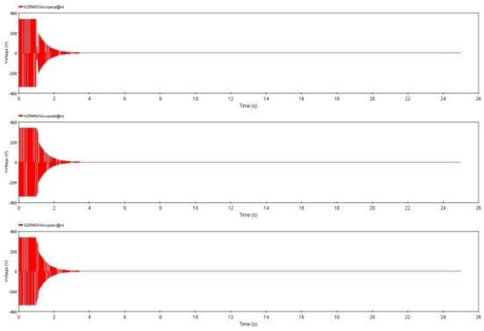


Fig.3. G2/Vscopesa@vn, G2/Vscopesb@vn G2/Vscopesc@vn

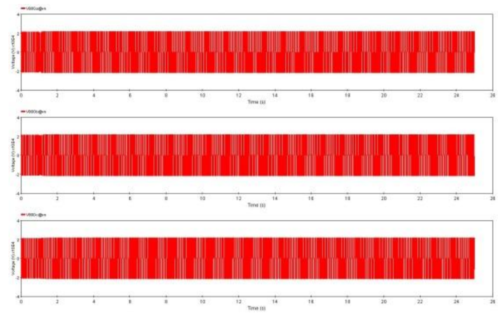


Fig.4 V800a@vn, V800b@vn V800c@vn

B. Switch Current

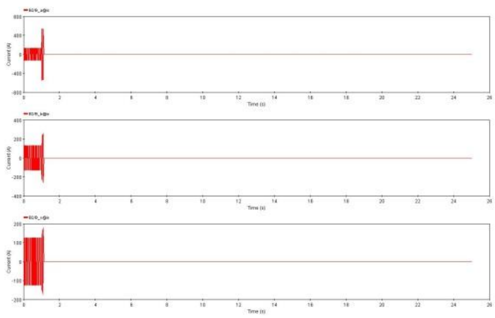


Fig.5. B1/B_a@is, B1/B_b@is B1/B_c@is

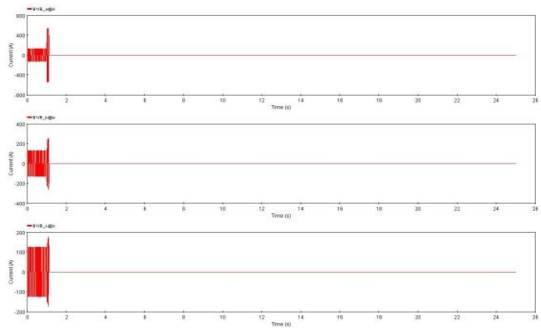


Fig.6 B2/B_a@is,B2/B_b@is B2/B_b@is

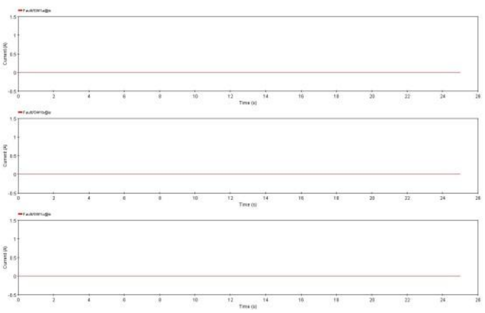


Fig.7 Fault/SW1a@is, FaultSW1b@is FaultSW1c@is

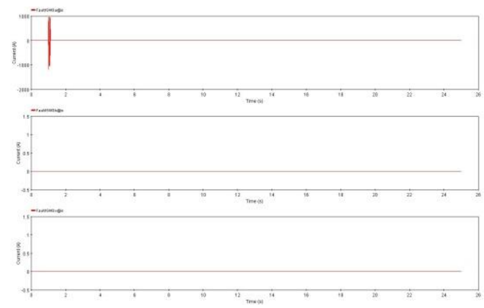
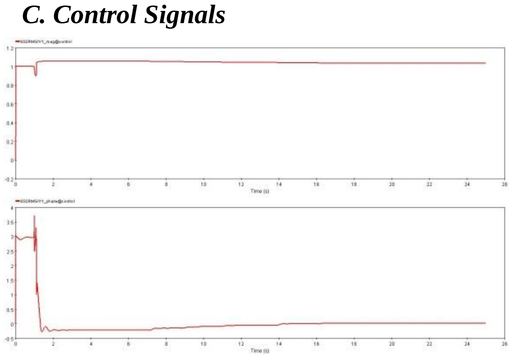


Fig.8Fault/SW3a@is,FaultSW3b@is FaultSW3c@is

C. Control Signals



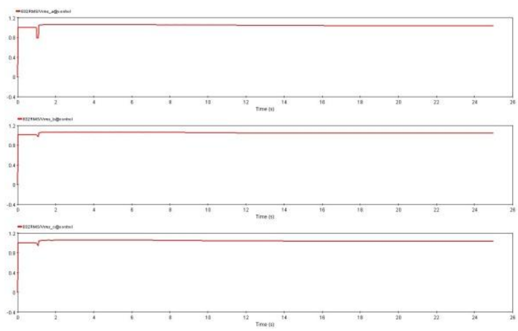


Fig.9832 RMS/V1_mag@vcontrol, *Fig.10 832 RMS/Vrms_a@control,*
832 RMS/V1_phase@control832 RMS/Vrms_b@control,832 RMS/Vrms_a@control,

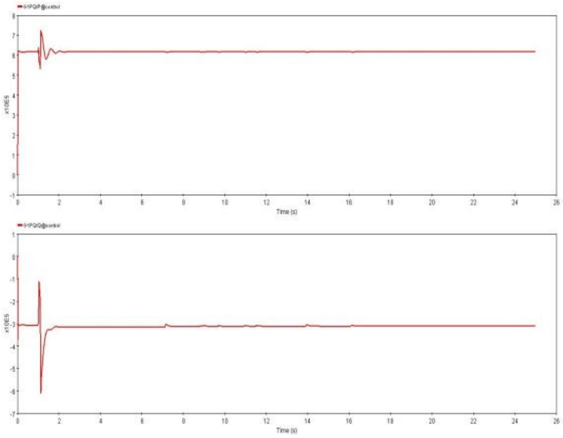


Fig.11 G1 PQ/P@control,
G1 PQ/Q@control

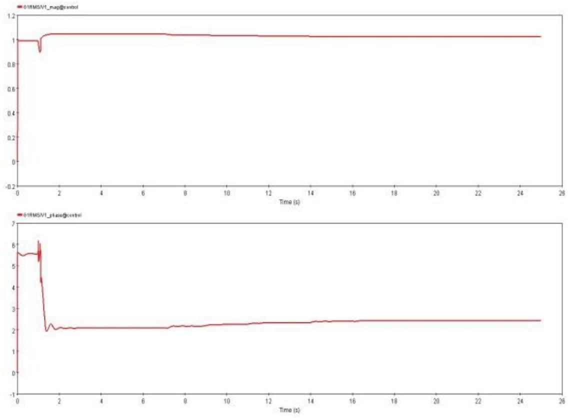


Fig.12G1 RMS/V1_mag@control
G1 RMS/V1_phase@control

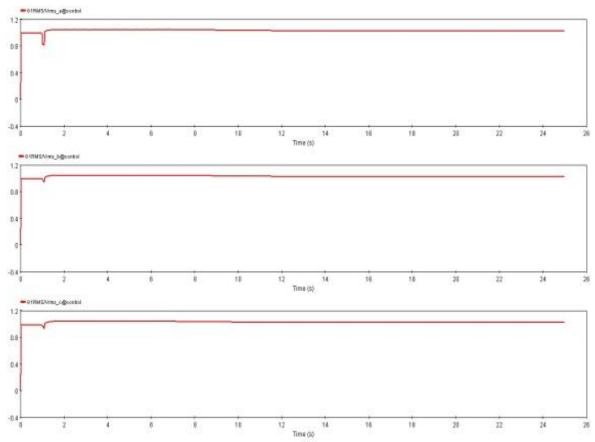


Fig.13G1RMS/Vrms_a@control,
G1 RMS/Vrms_b@control
G1 RMS/Vrms_c@control

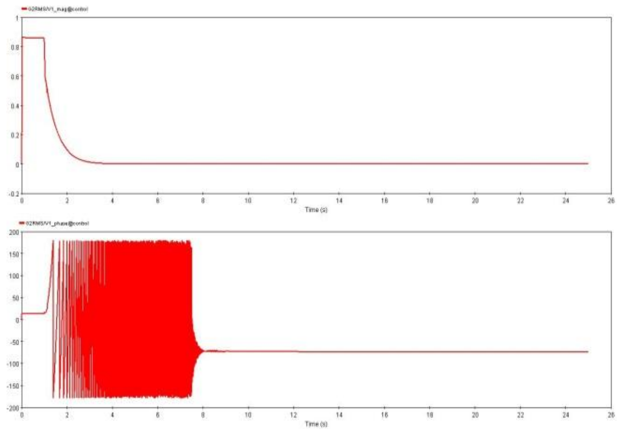


Fig.14G2RMS/V1_mag@control
G2 RMS/V1_phase@control

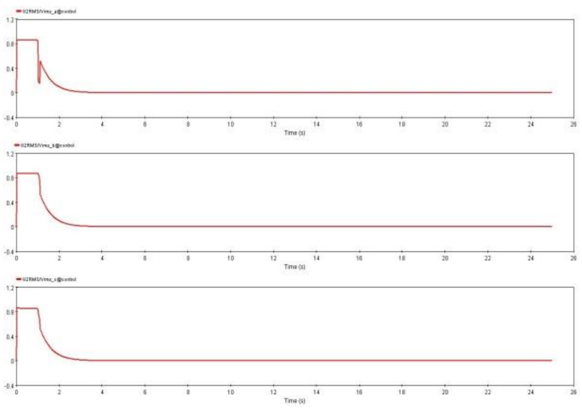


Fig.15 G2 RMS/Vrms_a@control,
G2 RMS/Vrms_b@control
G2RMS/Vrms_c@control

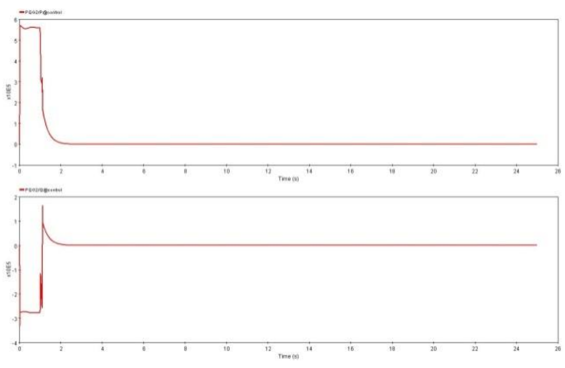
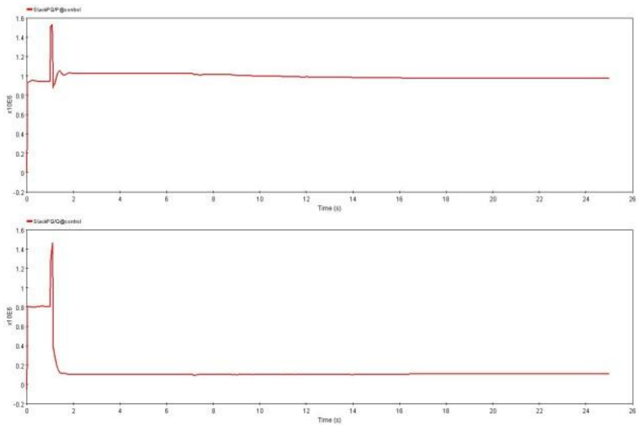


Fig.16PQ G2/P@control
PQ G2/Q@control



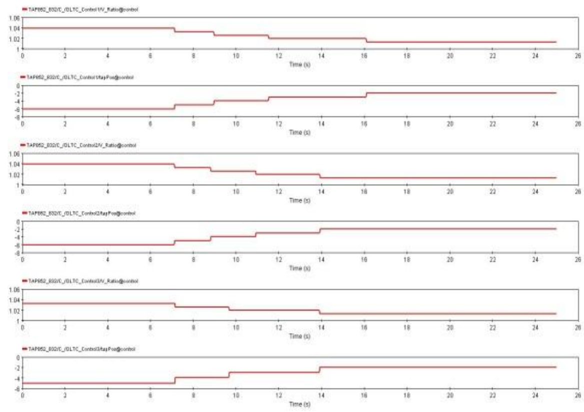


Fig.17Slack PQ/P@control,
Slack PQ/Q@control

Fig.18TAP852_832/C_/OLTC_Control1/V_Ratio@control

TAP852_832/C_/OLTC_Control1/tapPos@control

TAP852_832/C_/OLTC_Control2/V_Ratio@control

TAP852_832/C_/OLTC_Control2/tapPos@control

TAP852_832/C_/OLTC_Control3/V_Ratio@control

TAP852_832/C_/OLTC_Control3/tapPos@control

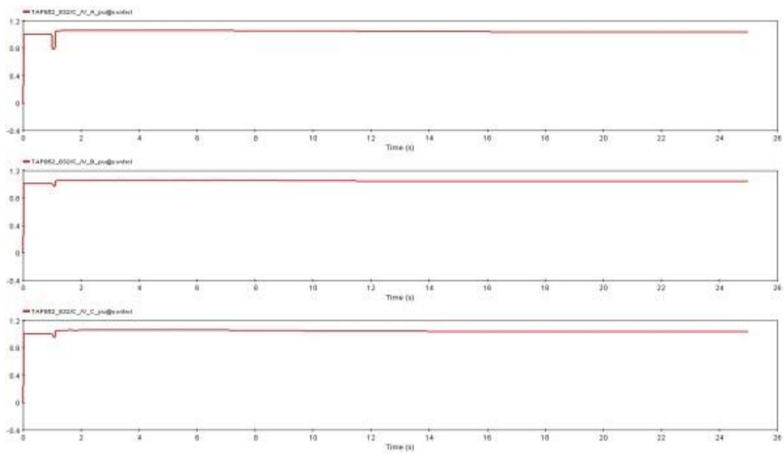
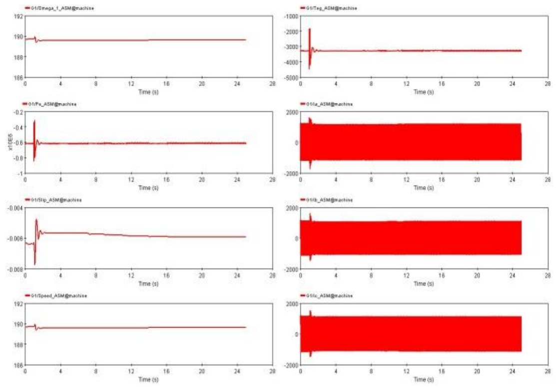


Fig.19TAP852_832/C_/V_A_pu control

TAP852_832/C_/V_B_pu control

TAP852_832/C_/V_C_pu control

D. Machine Parameters



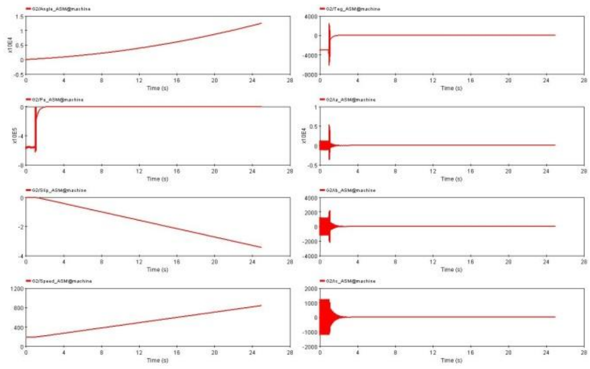


Fig.20G1/Omega_1_ASM@machineFig.21G2/Angle_ASM@machine

G1/Pe_ASM@machineG2/Pe_ASM@machine

G1/Slip_ASM@machineG2/Slip_ASM@machine

G1/Speed_ASM@machine G2/Speed_ASM@machine

G1/Teg_ASM@machineG2/Teg_ASM@machine

G1/ia_ASM@machine G2/ia_ASM@machine

G1/ib_ASM@machineG2/ib_ASM@machine

G1/ic_ASM@machineG2/ic_ASM@machine

Snapshot of Load flow analysis result

EMTP Simulation: C:\Users\student\Documents\EMTP\IEEE34_distribution_system\IEEE_34_Bus.net 7/6/2018, 10:30:32

	Ended			CPU: .06250s	
Iteration 3				Case web	Load-Flow web

Loaded Load-Flow solution data for saving specific device computations.

Saved device data computed from Load-Flow solution.

Ended Load-Flow solution 7/6/2018, 10:30:34

Elapsed clock time: 0:0:2.109

III. CONCLUSION

Load Flow Analysis has been performed on IEEE 34 Node test feeder using EMTP RV. The simulation results obtained proved that satisfactory performance has been achieved with the use of this software. It is not intended to compare with different software packages. Different Simulation results depicting Node voltages, switch currents and control signals has been analysed. The results clearly depict successful application of Load flow analysis on EMTP RV Software. The Future scope may include the comparison of results obtained in this Software with IEEE Published results of Load flow analysis.

IV. REFERENCES

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