A Unified Platform Enabling Power System Circuit Model Data Transfer Among Different Software

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***Abstract*— Diversity of software packages to simulate the power system circuits is considerable. It is challenging to transfer power system circuit model data (PSCMD) among different software tools and rebuild the same circuit in the second software environment. This paper proposes a unified platform (UP) where PSCMD are stored in a spreadsheet file with a defined format. Script-based PSCMD transfer applications, written in MATLAB, have been developed for a set of software to read the circuit model data from the UP spreadsheet and reconstruct the circuit in the destination software. This significantly eases the process of transferring circuit model data between each pair of software tools. In this paper ETAP, OpenDSS, Grid LabD, and DEW are considered. In order to test the developed PSCMD transfer applications, circuit model data of a test circuit and an actual sample circuit from a Californian utility company, both built in CYME, were exported into the spreadsheet file according to the UP format. Thereafter, circuit model data were imported successfully from the spreadsheet files into all above mentioned software using the PSCMD transfer applications developed for each software individually. Finally, load flow analysis is performed in all software and the obtained results match with each other.**

***Index Terms*— power system simulation; power distribution; load flow analysis; power engineering; computer aided engineering.**

I. INTRODUCTION

As power distribution systems are evolving into more complex networks, electrical engineers have to rely on software tools to perform circuit analysis [1]–[4]. Recent advances in engineering sciences have brought a revolution in power system software packages [5]–[11]. There are dozens of powerful software tools available in the market to simulate the power grid. Although their main functions are similar, there are differences in features and formatting structures to suit specific applications. This creates challenges for transferring circuit models between different software. Most utilities use some specific software package according to their needs or preferences, where each stores information about loads and circuit model in its own specific database structure.

With the emergence of new generation resources such as solar energy and wind energy, or new technologies such as power measurement units (PMUs) and micro PMUs [12]–[14], as well as new concepts such as smart grid or micro grid [15]–[18], new circuit phenomena including dynamic behaviors will need to be studied. Therefore, utilities may need to use different software tools to investigate these new phenomena, which may not be supported by their current software platforms. Thus, it becomes necessary to transfer power system circuit model data (PSCMD) from one software to another. However, PSCMD sharing among different software is a cumbersome process that can consume many person-hours. What is needed is a solution that enables cross-platform PSCMD transfer in the form of a complete power distribution network starting from the substation transformer all the way down to the load.

The objective of this paper is to develop a Unified Platform (UP) to facilitate transferring PSCMD among different software packages and relieve the challenges of the circuit model conversion process. UP uses a commonly available spreadsheet file with a defined format, for any home software to write data to, and for any destination software to read data from, via a script-based application called the PSCMD transfer application. The main considerations in developing the UP are to minimize manual intervention and import a one-line diagram into the destination software or export it from the source software, with all details to allow load flow, short circuit and other analyses.

In this paper, ETAP, OpenDSS, GridLab-D and DEW are considered. PSCMD transfer applications written in MATLAB have been developed for each of these to read the circuit model data provided in the UP spreadsheet. Each PSCMD transfer application has been verified by using two circuits, a test circuit and an actual circuit from a utility company for all the above listed software. When PSCMD is provided in the UP spreadsheet with defined format, successful reconstruction of the circuit in a destination software is achieved. Load flow analysis is performed in each software for both sample circuits and compared with the available results to verify the correctness of the circuit built by the PSCMD transfer application. The obtained results match accurately in all software for both circuits. The paper is organized as follows: Section II describes the UP and its functions. Section III presents simulation results to verify the effectiveness of the proposed UP and transfer process. Section IV compares features and capabilities of the mentioned software tools and highlights some specific issues, and Section V offers concluding observations.

II. Proposed Unified Platform Based on Spreadsheet

Conventionally, users develop their own tailor-made applications to transfer PSCMD from one software to another as needed. These applications are typically unidirectional, i.e. one specific application can transfer data from software #1 into software #2, but not vice versa. Therefore, if there are N different software packages,   applications will be required. This approach is quite wasteful since there are dozens of software packages in this field. To complicate things, each software has its own terminology. For example, software #1 may name a positive sequence resistance of cable “Line R1 Ohms” while software #2 may name it “Pos. Seq R”. Also each software has its own database structure to store their circuit model data. Another issue is the unit of component parameters. For example, conductor impedance can be in ohms or ohms per mile. Moreover, it is possible that one software package might consider certain parameters that other packages do not. Therefore, the developers of the PSCMD transfer applications need to be very familiar with both software and their internal languages (names of components and their parameter) in detail to be able to write the application properly. As noted earlier, different software may present This paper proposes UP to facilitate the PSCMD transfer process. As shown in Fig. 1, the proposed UP results in developing only two application for each software; one to read PSCMD from the UP spreadsheet file and transfer it to the destination software and the other one to read PSCMD from the source software and import it to the UP spreadsheet with defined format. Consequently, the number of applications required to share data among N different software is reduced from   to 2N. The PSCMD transfer applications that transform circuit model data from the UP spreadsheet to commercial software packages are written in the MATLAB. Each application is unique to the associated software.

The proposed UP consists of a spreadsheet file with a defined format containing several sheets to include specifications for bus/node, cable, capacitor bank, circuit breaker, generator, load, overhead line, transformer, etc. Each sheet is a library of the parameters of available components in the circuit with details to allow different power system studies. For instance, the sheet called cable contains the required parameters such as ID, from node, to node, phase configuration, positive sequence resistance, positive sequence reactance, positive sequence admittance, zero sequence resistance, zero sequence reactance, zero sequence admittance, length, current rating, etc. A snapshot of the UP spreadsheet is given in Fig. 2, illustrating the format and required parameters of some components such as transformer, cable, capacitor and load. It is worth mentioning that UP does not include the time-varying data to do time-series simulation since this depends on whether the specific software has the capability to do time-series simulation and if so, it depends on what format the specific software needs data to do time-series simulation. UP allows PSCMD transfer to and from the set of software, and it enables users to explore some new phenomena in their circuits by using a different software without the time consuming data transfer process. As mentioned previously, an individual application is developed in Matlab for each software tool including ETAP, OpenDSS, GridLAB-D and DEW to transfer PSCMD from UP into destination software.

It is worth mentioning that OpenDSS and GridLab-D are script-based tools where all components and their parameters and connectivity are assigned in the script-based environment. In other words, they do not have any Graphical User Interface (GUI) to drag and drop a component (e.g., load) from their library and make any connection to another component (e.g., cable). Moreover, they do not have any built-in feature yet to import PSCMD from a spreadsheet/access file, for example, as ETAP and DEW do. Therefore, it will take a long time to create any industry-level circuit in OpenDSS and GridLab-D containing hundreds of lines, cables, loads etc. For instance, the general scheme of importing PSCMD from the UP spreadsheet into OpenDSS and GridLab-D using the developed applications is illustrated in Fig. 3.

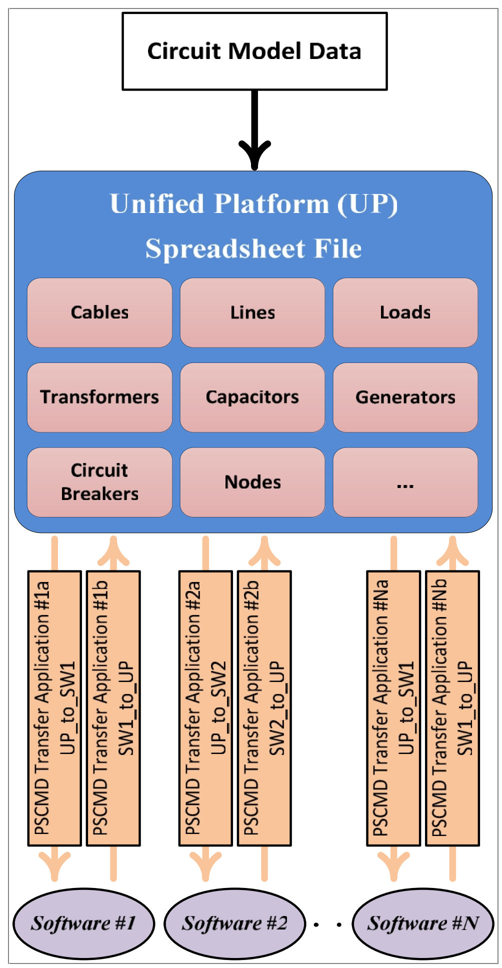

Fig. 1. Conceptual illustration of the proposed unified platform (UP) to transfer power system circuit model data among different software. SW stands for software.

(a)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
(a)	Section Id	From Node	To Node	Cap Nom (kVA)	Prim Volt (kVLL)	Sec Volt (kVLL)	X0 R0 Ratio	X1 R1 Ratio	Z0 (%)	Z1 (%)	Primary Config	Secondary Config		
	TR1	N5	N9	1500	12	0.48	10	10	6	6	D	Yg		

(b)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
(b)	Section Id	From Node	To Node	Phase	Line R1 Ohms	Line X1 Ohms	Line B1 uS	Line R0 Ohms	Line X0 Ohms	Line B0 uS	Length ft	IA (Amps)	IB (Amps)	IC (Amps)
	C1	N1	N2	ABC	0.01	0.012	12.091	0.054	0.015	12.091	341	473	473	473

(c)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
(c)	Section Id	From Node	Cap. Control	Cap. Status	kV	Total Cap. Kvar	Phase	Config	Sensing ON	Sensing OFF	PT Ratio			
	CAP2	N4	Voltage	On	7.2	1200	ABC	Y	121	126	60			

(d)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
(d)	Section Id	From Node	Phase	Config	Spot kVAR A	Spot kVAR B	Spot kVAR C	Spot kW A	Spot kW B	Spot kW C				
	LD1	N10	AB	Yg	600	360	0	800	480	0				

Fig. 2. Snapshot of UP's spreadsheet containing required parameters of: (a) transformer; (b) cable; (c) capacitor and (d) load.

III. Simulation Results

In order to verify the effectiveness of the proposed UP and test the functionality of developed PSCMD transfer applications, the circuit model data of two different sample circuits were imported into ETAP, OpenDSS, GridLAB-D and DEW using the developed PSCMD transfer applications: (1) a test circuit built by authors as an example and (2) an actual sample circuit from a California utility. The load-flow analysis of structured circuits is performed in each software and the obtained results are compared with provided results from CYME to check the correctness of structured circuits. The following is general information about two imported circuits:

- The circuit model data of the test circuit contains 6 loads which are illustrated in Table I; two 1200-kVAR capacitor banks connected to nodes N4 and N8; 10 nodes (N1 to N10); 5 cables; one overhead line; and one transformer (12/0.48 kV) connected between nodes N5 and N9.
- The actual sample circuit from California utility contains 39 loads with total rating of 6.4 MW and 4 MVAR; four 1800-kVAR capacitor banks (two of which are connected to the grid in this case of study); 291 nodes; 119 cables; 36 overhead lines; 10 PV generators with total capacity of 5 MW; and 10 transformers (12/0.21 kV).

The obtained load flow results for both test and actual sample circuits are illustrated in Table II and Table III, respectively. We note that the obtained results match precisely with each other as well as results available from CYME, which confirms the correctness of the reconstructed circuit and the proper functionality of PSCMD transfer applications to transfer the circuit model data from UP spreadsheet to each software.

IV. Discussion

While the conversion process was successful for all four software tools in this paper, there are several differences among their features that merit discussion and are summarized in Table IV.

• ETAP and DEW have a GUI to drag and drop components from a library, while both OpenDSS and GridLAB-D have a script-based environment. Thus, users of OpenDSS and GridLAB-D need to write a text file according to the language of related software to define all components, parameters as well as their connectivity.

• ETAP has a useful feature to display a visual circuit schematic even if the XY coordinates of nodes are not imported into ETAP, which helps in the debugging stage. OpenDSS and DEW require XY coordinates to create a circuit schematic. GridLAB-D does not produce a schematic at all.

• GridLAB-D, OpenDSS, and DEW can model the line/cable based on ABC (phase-to-phase) format of line/cable impedances, while ETAP cannot. Moreover, ETAP, OpenDSS, and DEW can model the line/cable based on PNZ (positive-negative-zero) sequence format of line/cable impedances while GridLAB-D cannot.

• Software varies in its capability to model the capacitance of lines/cables, which can be important in distribution level circuit studies since the capacitance of underground cable is considerable and may have a significant impact on the load flow results. ETAP, DEW and OpenDSS have this capability while GridLAB-D does not. According to the simulation results shown in Table II and III, however, GridLAB-D load flow results nevertheless match with the others.. The reason for this is that the capacitances of lines/cables are imported as individual capacitors (such as load) at the beginning and ending-point of lines/cables in the PSCMD transfer application.

• The voltage rating of all nodes should be assigned one by one in GridLAB-D, while ETAP, OpenDSS and DEW get it automatically after connecting the main feeding point and assigning the connectivity of the circuit.

Table I: Load Summary of Test Circuit.

Name	Node	kW	kVAR	Voltage Rating	Power Factor (%)
LD1	N4	3000	1800	7.2 kV	80
LD2	N5	4500	2700	7.2 kV	80
LD3	N7	3000	1307.7	7.2 kV	90
LD4	N8	1500	653.7	7.2 kV	90
LD5	N9	1500	900	0.48 kV	80
LD6	N10	3000	1800	7.2 kV	80

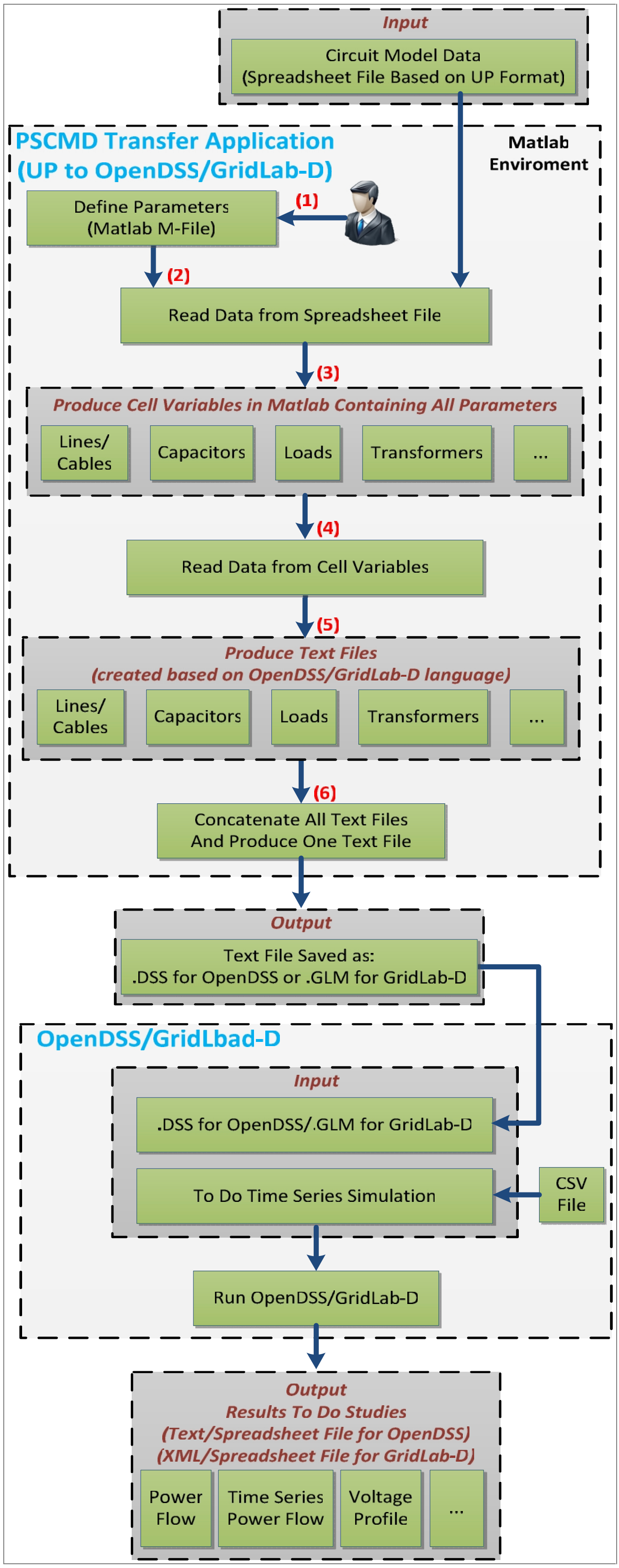

Fig. 7. General scheme of importing power system circuit model data from UP spreadsheet into OpenDSS/GridLab-D using PSCMD transfer application.

V. Conclusion

Emerging technologies are introducing new devices and phenomena to power distribution circuits, creating a need for new software capabilities to investigate them since the existing software may not support them. Consequently, users may need to transfer their PSCMD among different software tools to take advantage of specific features in new software. Due to the considerable diversity of software tools on the market to simulate and study power system circuits, it has been a challenge to transfer PSCMD and reconstruct circuits in different software tools. With the UP scheme proposed in this paper, all PSCMD are presented in a spreadsheet file based on a single defined format. As a result, only two unidirectional applications are required to transfer PSCMD from the UP spreadsheet into any one software and vice versa, instead of a combinatorial number of conversion applications between multiple software. In this paper, PSCMD transfer applications were developed in MATLAB for ETAP, OpenDSS, GridLAB-D and DEW and tested on two circuits to confirm that the load flow results agree and the circuit conversions have been successful.

The conversion applications presented in this paper is available to utility engineers and researchers to facilitate their work. Future development may expand the conversion applications to include other commonly used software tools.

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TABLE II: LOAD FLOW RESULTS OF TEST CIRCUIT.

Bus	Active Power (kW)					Reactive Power (kVAR)				
	Original (CYME)	**ETAP**	**OpenDSS**	**GridLAB-D**	**DEW**	**Original (CYME)**	**ETAP**	**OpenDSS**	**GridLAB-D**	**DEW**
N1	14527	14536	14534	14535	14528	7982	7989	7988.7	7988.6	7986
N2	14510	14518	14516.8	14517	14513	7963	7969	7969.4	7969.2	7968
N3	14510	14518	14516.8	14517	14517	7963	7969	7969.4	7969.2	7969
N4	14501	14509	14508	14508.6	14508	7954	7960	7961.4	7961.25	7957
N5	8925	8931	8930.4	8931.51	8927	4852	4857	4857.2	4857.65	4855
N6	4117	4120	4119.6	4120.16	4115	1141	1144	1144.1	1144.17	1144
N7	4050	4053	4052.4	4052.9	4053	1045	1048	1047.7	1047.94	1047
N8	1349	1350	1349.8	1350	1349	-265	-263	-263.1	-263.5	-263
N9	1199	1200	1199.9	1200	1200	899	900	899.9	900	900
N10	2400	2400	2400	2400	2400	1800	1800	1800	1800	1800

TABLE III: PARTIAL LOAD FLOW RESULTS FROM ACTUAL SAMPLE CIRCUIT.

Bus	Active Power (kW)					Reactive Power (kVAR)				
	Original (CYME)	**ETAP**	**OpenDSS**	**GridLAB-D**	**DEW**	**Original (CYME)**	**ETAP**	**OpenDSS**	**GridLAB-D**	**DEW**
90091686_02658 (c104)	276	277	276.7	276.7	272	167	167	166.3	166.8	166
PME4896-3_02658 (sw123)	357	357	356.9	356.9	358	224	223	223.1	223.24	222
833E_02658 (sw94)	380	380	380	380.1	378	238	237	237	237.2	239
107988591_02658 (c95)	403	402	402	402.3	401	252	253	252.8	252.9	254
GS0713-2_02658 (sw46)	449	447	447	447	448	273	275	264.9	271.25	263
PME4896-4_02658 (C73)	550	552	550	549.2	554	-1348	-1349	-1358	-1363	-1356
J057-1P_02658 (SW113)	576	576	575.5	575.5	575	360	360	359.3	359.3	361
PME5100-1_02658 (C25)	805	806	805.6	805.6	811	-1233	-1226	-1232.5	-1225.4	-1229
RCSG777-3_02658 (sw111)	833	827	832.1	832.6	836	1098	1101	1103.9	1105.1	1099
PMH5099-3_02658 (sw60)	1106	1105	1105.4	1105.5	1104	693	693	692.8	693.18	689
48201834_02658 (c92)	1255	1253	1252.8	1252.8	1253	-970	-960	-967.6	-958.8	-966
PMH5099-4_02658 (c20)	1717	1716	1715.5	1715.7	1719	-2419	-2402	-2415.9	-2400	-2398
RCS5187-4_02658 (c19)	2827	2826	2825.7	2826.3	2825	-1730	-1712	-1727.1	-1710	-1707
RCS5187-3_02658 (sw16)	3150	3147	3146.7	3147.3	3153	-1528	-1509	-1524.4	-1507.4	-1314
148639376_02658 (c89)	3584	3584	3581.2	3583.7	3748	-1301	-1278	-1299.2	-1274.2	-1294
PS0372_02658 (sw7)	4207	4209	4205.5	4208.7	4211	-912	-893	-914.9	-888	-904
02658	3723	3726	3720.9	3729	3725	542	557	547.8	585	574