AC 2008-282: A VISUAL LEARNING TOOL FOR PRESENTATION OF THE ECONOMIC DISPATCH TOPIC

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A Visual Learning Tool for presentation of the Economic Dispatch Topic

Abstract

Computer modeling and simulation has emerged as one of the most cost effective ways for providing supplements to course lectures in diverse areas of engineering. Power systems engineering has a long history of this and has seen a range of power systems programs for commercial and educational applications. In educational contexts the simulation tool brings more clarity to concepts that are challenging for students, as well as enabling the instructor to use class instruction time more efficiently.

This paper presents a simulation tool designed to enable students gain better insight into the numerical solution of the classical Economic Dispatch Problem (EDP). The MATLAB® -based program visually guides the user through the computational process involved in iteratively computing the economic dispatch solution for a 9-bus power system. This simulation program serves as a tool for managing classroom time and for presenting EDP with clarity, without getting bogged down with details of the analysis.

INTRODUCTION

The merits of using digital modeling and simulation in power engineering education as a means for bringing clarity to presentation of concepts is well articulated and documented in research articles [1-6]. The digital tool becomes more attractive especially when the curriculum is so crowded that the instructor must rush through a number of important topics during the semester.

The economic dispatch problem (EDP) is a classical power systems (PS) analysis problem that is broached briefly at the introductory level in typical electrical engineering (EE) undergraduate programs. The question that presents itself is: What is the most efficient way of introducing the topic given the fact that there are so many other topics that are deemed appropriate or important for a first course in power systems? Furthermore, it is very likely that this first course in power would end up as the only power related course that many EE students encounter for the duration of their undergraduate studies.

Certainly, a very efficient presentation technique becomes not only appropriate, but attractive as well. Commercial power systems analysis software are very effective in presenting a neat and organized model of the power system, and serve as a good introductory avenue for presenting system analysis problems to a new student. However, a significant amount of time within the typical 16-week curriculum is required to become familiarized with the power system software, so that students could take advantage of the visual analysis aid that it provides. The typical power system software offers the user a very convenient representation of the system in terms of basic elements such as transmission lines, transformers, power sources, connected loads, etc. The modeling of the network is usually done with a convenient drag and drop one-line diagram representation. The resulting data at buses, lines and other critical or important system elements are then dumped into some form of case summary report or displayed on the one-line diagram.

Some power systems software go a step further in making the data and visual process come alive by animating several features. PowerWorld® [7] software is a very good example of this. The simulation environment offers visual cues that provide benefit to the learner, especially a new student in PS analysis course. PowerWorld® grants the user the ability to look at line flows, examine node variables and other kinds of indicators. A vast range of network variables can be displayed, and in real time the user may change some network parameters and observe the effect of the changes through animated variables. A user could also go behind the animation to examine system data and results, such as YBus, voltages, etc.

Power systems simulation programs typically do not consider it necessary to guide the user through the process or stages involved in the computation. This would be a departure from the fundamental purpose of the software. For instance, while the power system program is executing a load flow using the Newton-Raphson (NR) algorithm, it simply displays the final results as convergence is attained. The user does not have access to the computational process or procedure as it is usually well laid out in the typical flowchart. For the learner taking the first course in the power area it would be beneficial to have some understanding or overview of the computation process without devoting more time than could be afforded, with consideration given to other materials that must be covered in the same class. It seems attractive to explore some visualization techniques or method that would enable an instructor to clearly and efficiently present an overview of the topic to students.

This paper presents a visual method for aiding the student in gaining better insight into the numerical solution of the economic dispatch problem. A MATLAB® -based [8] program is designed for visually guiding the user through the computational process involved in iteratively computing the economic dispatch solution for a given 9-bus network. The purpose is to enable the learner to have a clearer understanding of the process and to have a good overview of what goes on behind the typical power system simulation software when the economic dispatch problem is being solved. It must be emphasized that this is not an attempt to create or recreate another power system simulation and analysis program; there are a variety of good commercial programs on the market.

This is not intended to do the same things found in commercial software packages. Rather, this is a tool to aid students in the learning process.

MATLAB® -BASED VISUALIZATION OF EDP SOLUTION

In order to create a learning tool that would be readily accessible to students and educators, the programming environment must be widely available and quite familiar to the targeted audience. This would naturally remove the time element associated with learning about the tool and therefore, all efforts would be concentrated on learning the EDP solution (Appendix).

MATLAB® software package seems to be the best option and most suitable given its wide adoption in many EE programs.

A 3-generator, 9-bus system example from a familiar textbook [9] is used as the basis for learning EDP as presented in this paper. The objective is to develop a flowchart of the solution algorithm that is dynamic, and that changes as the computation goes through the iterative steps in the solution of the EDP using the Lagrange multiplier method. The lines are assumed to be lossless for the case study presented in this paper. The first interface a user is presented (Fig. 1) has two sections; the left hand side is blank with the start button and the right hand side has the reset button, a pull down panel for selecting the transmission line to eliminate, followed by quadratic cost function coefficients for the three generators and the line parameters. The user may modify cost functions and line parameters as desired. Program execution starts by clicking the start button. The user notices a box that indicates the data that should be available and assembled before computation of the EDP solution begins. The box shows the YBus matrix, initial values for solving the load flow problem, counters and convergence parameters. The initialization is done at the beginning of the program. This helps the student to make important connections with the EDP algorithm that is presented in the textbook. A very brief overview of the textbook presentation of the solution algorithm is expected to precede this step.

Students would notice that the YBus is affected only by changes to the line values. The process continues as the user clicks on the "Iterate" button. The "Iterate" button gets the user to begin the first iteration of the EDP solution. At that point a load flow is solved for the 9-bus system in the background. The solution is indicated following the initialization box (Fig. 2). Then, it shows the user the next set of parameters to compute before the Lagrange multiplier problem is solved. The parameters include power losses, the system Jacobian matrix, the incremental transmission losses (ITL) when losses are considered. It then solves the problem using the Lagrange multiplier method and finally comes up with the incremental cost (IC), the scheduled power for the generators, and the check for convergence. If the convergence criterion is not met, obviously no solution is obtained. The user notices the counter incremented and the process continues until the final iteration. Fig. 3 shows the computation of the real and reactive bus powers resulting from the load dispatch and the line flows after convergence of the solution. The student is able to modify the cost function parameters for any of the three generators and line impedances so as to observe how they impact the number of iterations, incremental cost, total cost, and line losses.

In addition to the flowchart algorithm this learning tool presents a display of power system transmission lines-flows, bus values and different entities connected on the bus in pictures (not symbolic). The purpose is to further reinforce learning by helping the student connect the simulation experience with real life power system.

STUDENT EVALUATION OF THE LEARNING TOOL

The visual learning tool was tested in an introductory power systems analysis course that serves as a senior-level elective. The course cover modeling of power system elements, per-unit representation and analysis of balanced and unbalance systems using symmetrical components. Also, students learn to use PowerWorld® software package in the course. The focus on computational aspects of a power system (power flow, economic dispatch, etc.) is reserved for a second elective course in the power area.

Thirteen students enrolled in the course completed a questionnaire designed to obtain some qualitative measure of effectiveness of the visual learning tool. The result of the test is summarized on Table 1. Students rate the tool as helpful, intuitive and easy to use, with an average score of 4.0 or over out of a maximum of 5.0. Similarly, there is a high interest in further exploring power system topics. At a slightly lower average of 3.77 students indicated that they have a "fairly good" understanding of the economic dispatch problem after the very limited exposure to the subject. This should be viewed as positive, granted that the total time of exposure to the concept is limited to about an hour.

CONCLUSIONS

The visual learning tool presented in this paper addresses some challenges for educators and students striving to cover many topics within the scope of an ever shrinking course instruction time. Although the tool is specifically applied to the solution of the economic dispatch problem in the work presented, the concept could be applied to other analytical processes. Other numerical algorithms typically discussed in power systems courses, such as load flow, unit commitment, etc. could be taught using this visualization approach. The dynamic flowchart enables students to quickly grasp the intricate flow of computational information which would otherwise be very confusing in the rush to move on to other topics. By choosing MATLAB® package as the primary simulation environment the visualization tool is made more accessible to students and educators because of its wide adoption. Moreover, learning time is more efficiently used as many students are already familiar with MATLAB®.

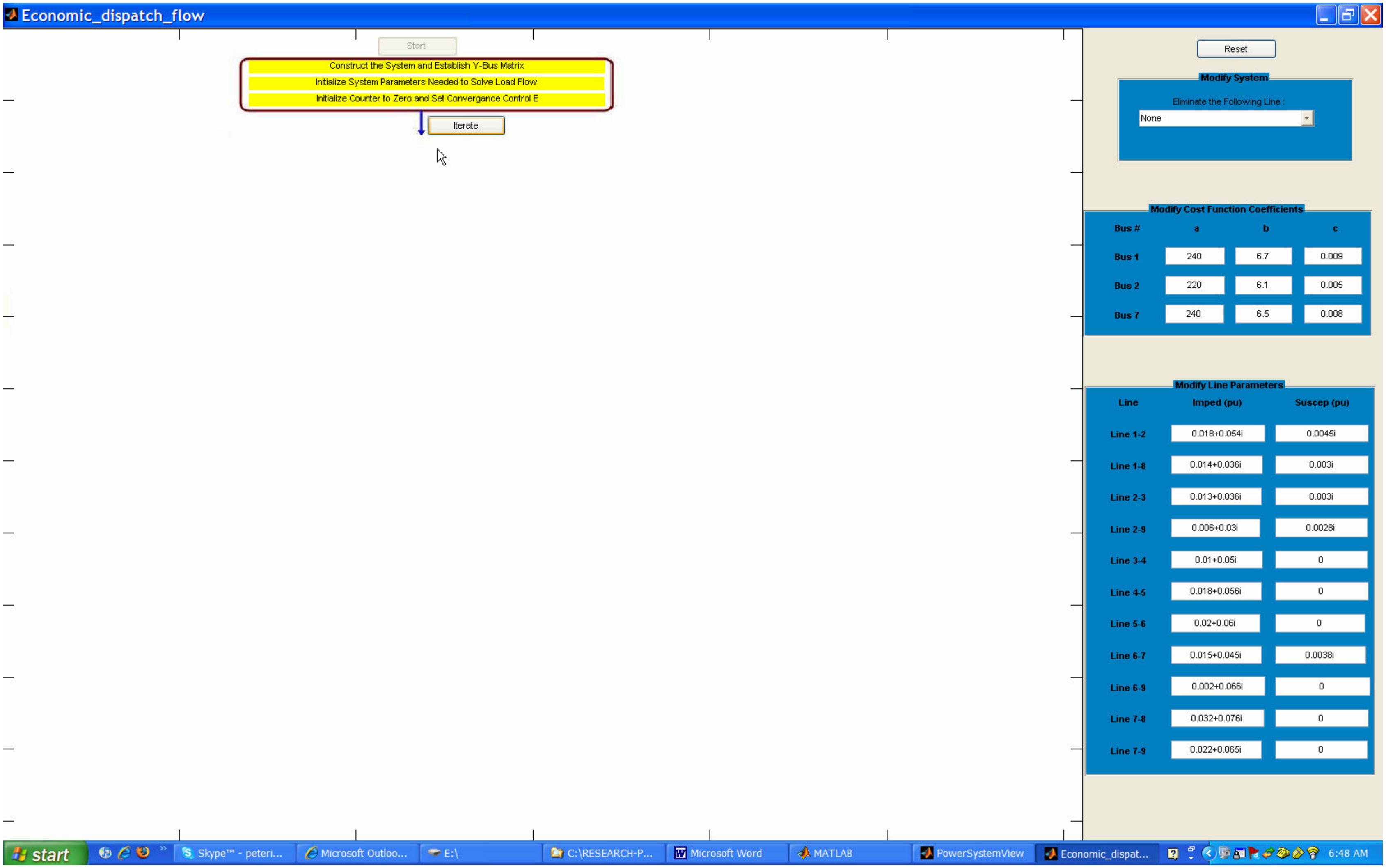

Fig. 1. EDP Visualization tool – Basic Interface.

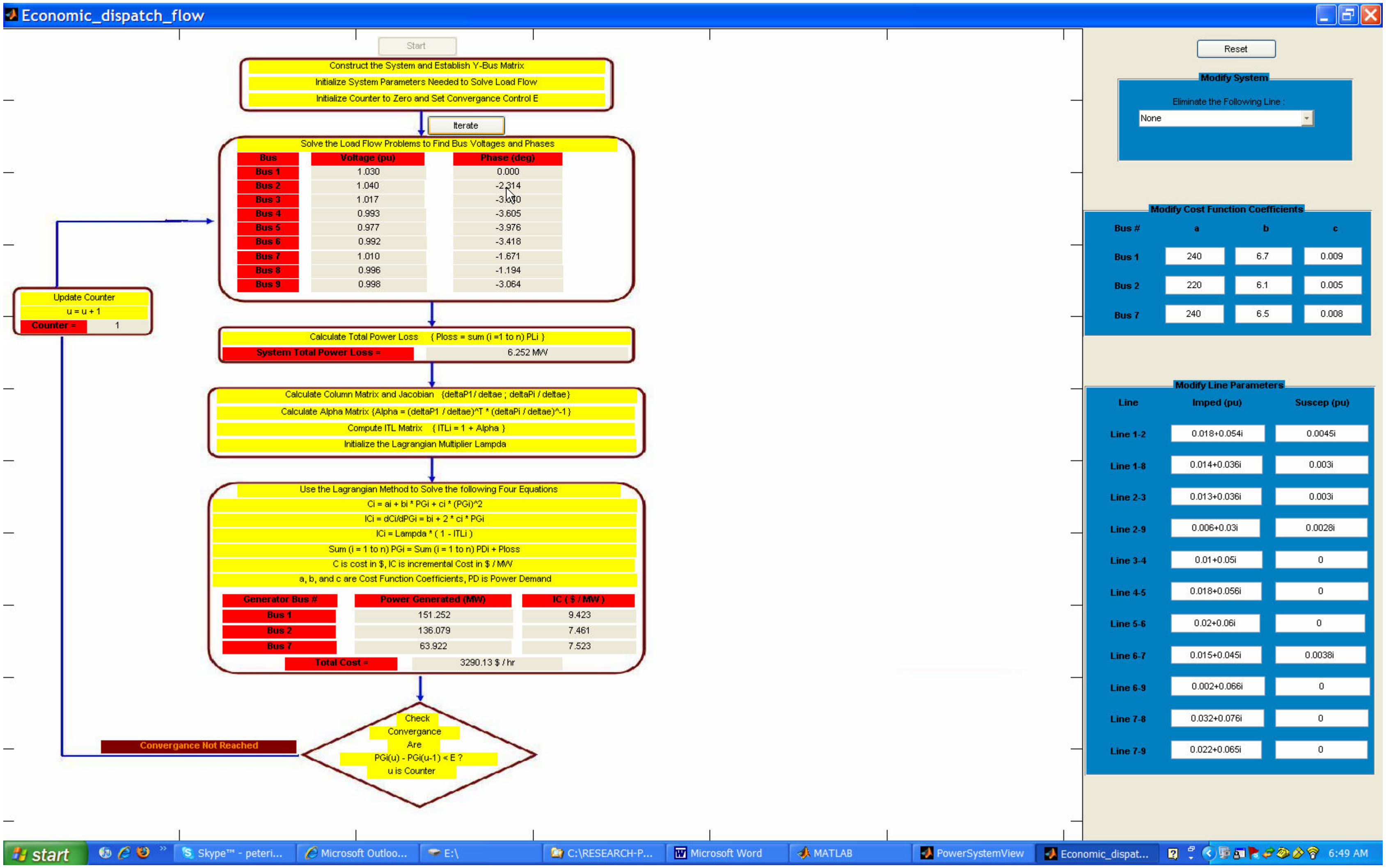

Fig. 2. EDP Visualization tool – Following first iteration.

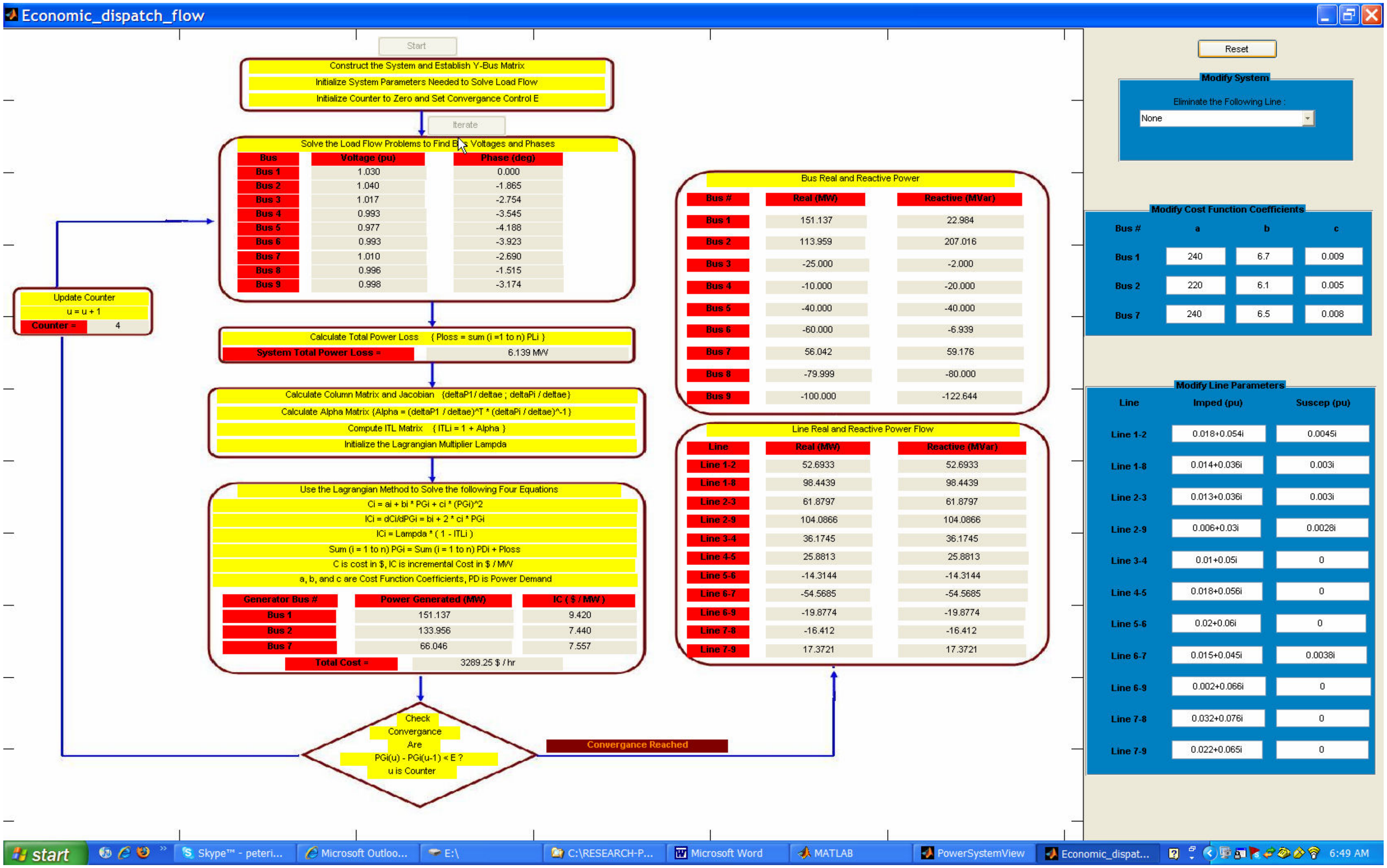

Fig. 3. EDP Visualization tool – Following solution convergence.

Table 1. Evaluation of the Economic Dispatch Computation Visualization Tool.

1. Rate your prior familiarity with economic dispatch problem								
	Not Familiar 0	1	2	3	4	Very Familiar 5	Average	Percentage
	6	3	3	0	1	0	1.00	20.00
2. The visualization tool was very helpful in understand the economic dispatch problem								
	Not Familiar 0	1	2	3	4	Very Familiar 5	Average	Percentage
	0	0	0	2	7	4	4.50	83.08
3. The visual learning tool for economic dispatch is intuitive and easy to use								
	Not Familiar 0	1	2	3	4	Very Familiar 5	Average	Percentage
	0	0	0	2	9	2	4.00	80.00
4. After using this tool I now have a fairly good understanding of the economic dispatch problem								
	Not Familiar 0	1	2	3	4	Very Familiar 5	Average	Percentage
	0	0	1	3	7	2	3.77	75.38
5. Given the opportunity I will like to further explore power systems analysis topics								
	Not Familiar 0	1	2	3	4	Very Familiar 5	Average	Percentage
	1	0	0	1	7	4	3.92	78.46

Appendix

Economic dispatch problem for N generator system [9]:

Minimize $C_t = \sum_{i=1}^{N} C_i(P_{gi})$; subject to: $\sum_{i=1}^{n} P_{gi} = P_L + P_D$

Where $C_i = \alpha_i P_{gi}^2 + \beta_i P_{gi} + \gamma_i$.

C_i is the fuel cost function and P_{gi} is the power output of unit i. α_i, β_i, and γ_i are quadratic cost function parameters. C_t is the total cost, while P_L and P_D are the total loss and demand respectively.

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