EFFECTIVE TEACHING OF POWER SYSTEM ANALYSIS COURSE USING PSCAD

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Abstract—**Power System Analysis (PSA) is one of the important courses that is offered for undergraduate students of Electrical engineering branch. This paper focuses on an efficient method to teach the PSA course using PSCAD. This is used as an instructional tool to complement the teaching of the subject matter. This would certainly improve the understandability of the subject. The proposed teaching methodology is illustrated through examples based on fault analysis. Initially, the analysis is illustrated using conventional approach prior to solving it through PSCAD software. Finally, a comparison of teaching by both the methods in terms of the program outcomes for the said course is presented.**

Keywords—PSCAD; Power Systems; Symmetrical Components; Sequence Networks; Symmetrical Faults; Unsymmetrical Faults; Fault Current; Sub transient current;

INTRODUCTION

Power system analysis is a major subject in Electrical Engineering course. It is a challenge to teach this course effectively, since the analysis involves more mathematical equations. It is also difficult to implement real-life power system for demonstration in the laboratory.

Traditionally, the subject is taught by considering a power system network, to which, the equations governing the type of study are applied and the results are obtained.

Fault in a power system is an abnormal condition, caused by equipment failures, insulation failure, flashover, physical damage or human error. These faults may either be three phase in nature involving all three phases in a symmetrical manner, or may be asymmetrical where only one or two phases may be involved. The fault analysis of a power system is required in order to provide information for the selection of switchgear, setting of relays and stability of system operation. A power system is not static but changes during operation. Hence, fault studies need to be routinely performed.

Even though the effects of fault on the power system can be mathematically illustrated, it does not give a visual scenario of the power system.The exposure to the use of computer technique will certainly benefit the student; where in a student can visualize the scenario of a power system through graphical interface. In this paper, an effort has been made to illustrate the fault analysis in a power system network using PSCAD software that will help the students to understand the concepts in a better manner. In the curriculum, practical sessions are not included for this course.

The topics that are discussed and demonstrated in this paper include Symmetrical three phase fault analysis and Unsymmetrical fault (LG, LL, and LLG) analysis. For each of the above topics, the paper provides (i) the theoretical background, (ii) a numerical example solvable by hand-calculations, and (iii) the corresponding solution obtained from PSCAD Software.

POWER SYSTEM COURSE

In the curriculum for an undergraduate, under the umbrella of the Power Systems, a number of courses are offered that are distributed over the period of the study. The courses that are offered are

(i) Electrical Power Generation
(ii) Transmission and Distribution
(iii) Power System Analysis
(iv) Utilization of Electrical Power
(v) Renewable Energy Sources
(vi) Computer Techniques in Power Systems
(vii) Switchgear and protection
(viii) Power System Operation and Control
(ix) High Voltage Engineering
(x) Electrical Power Quality.

Some of the topics in these courses can be made more interesting to the students through computer simulations. To list a few: fault analysis in Power System Analysis course, load flow analysis in Computer Techniques in Power Systems course, transmission line field effects and corona analysis in Transmission and Distribution Course,integrating renewable sources to the grid and analysis of the power quality.

SIMULATION SOFTWARE PACKAGES AVAILABLE

Many commercial power system simulation software packages are available from different vendors. Listed below are some of these packages:

(i) PSCAD/EMTDC
(ii) MATLAB/SIMULINK
(iii) MIPOWER
(iv) ETAP etc.

In this paper, the simulations are carried out using PSCAD. Some of the attractive features of this software are:

1. It is easy and user friendly to build, simulate, and model the systems.
2. It also provides limitless possibilities in power system simulation.
3. A comprehensive library of system models ranging from simple passive elements and control functions, to electric machines and other complex devices is available.
4. It uses graphical user interface to sketch virtually any electrical equipment and provide a fast and reliable solution [5].
5. PSCAD/EMTDC represents and solves the differential equations of the entire power system and its control in the time domain (both electromagnetic and electromechanical systems) [6].
6. It employs the well-known nodal analysis technique together with trapezoidal integration rule with fixed integration time-step. It also uses interpolation technique with instantaneous switching to represent the structural changes of the system [6].
7. Free version of the software is available, which can be downloaded and the simulations can be carried out at any point of time. Hence, the students are not restricted by the lab timings. Using free version, the students can simulate small systems, evaluate the software and it can be used as an educational tool. It is a fully featured edition, limited only by network size and certain functionalities [4].

In the following section, different types of fault analysis are carried out through simple numerical examples. The analysis is carried out using conventional method as well as using PSCAD software and the results are compared.

FAULT ANALYSIS

A fault in a power system is any failure which interferes with the normal operation of the system. The faults occurring in a power system can be either symmetrical faults or unsymmetrical faults.

Symmetrical Faults

In this case, the fault current is the same in all the three phases and hence the system remains balanced even after fault occurrence. Therefore the three phase system can be reduced to single phase system and study can be carried out. The knowledge of the amount of fault current flowing in the circuit on occurrence of the fault is necessary for the efficient disconnection of the healthy section of the power system from the faulty section in less time so that the healthy section continues to work without much disturbance.

The fault analysis is carried out for the following case studies.

Case Study 1: The single line diagram of a sample network is considered as shown in Fig.1, where the synchronous generators are unloaded and a symmetrical three phase fault occurs on the high voltage side of the transformer.

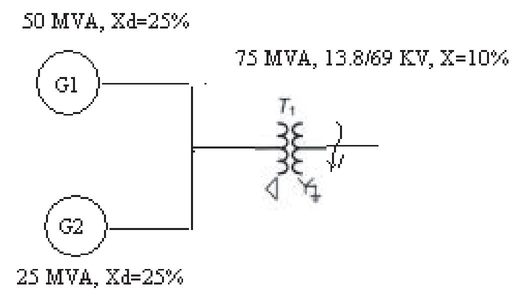

Fig.1: Single Line Diagram

The equivalent reactance diagram of the system is as shown in Fig. 2:

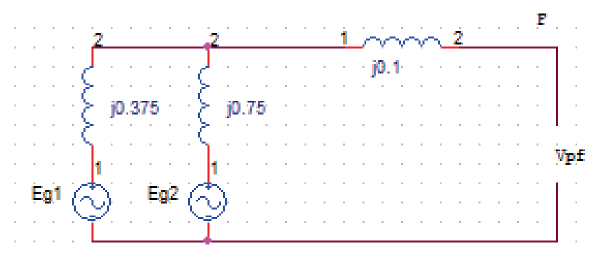

Fig 2: Equivalent reactance diagram

Prefault voltage on the HV side==0.957 p.u …………(1)

Equivalent reactance as visualized from the fault point is j0.35 p.u.

Hence, the sub transient current in the short circuit= I_f''== $2.735\angle{-90^0}$p.u. ………………….. (2)

Even though the numerical solution is obtained as illustrated above through mathematical equations, it does not give a visual scenario for understanding the situation. The above example could be made more interesting through simulation using PSCAD. The simulation model and the results are as shown in Fig.3 and Fig.4 respectively:

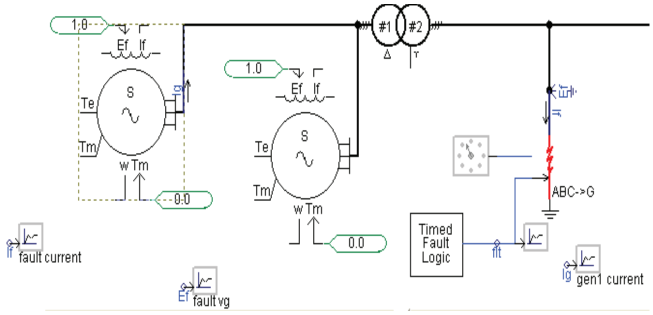

Fig. 3: Network in PSCAD

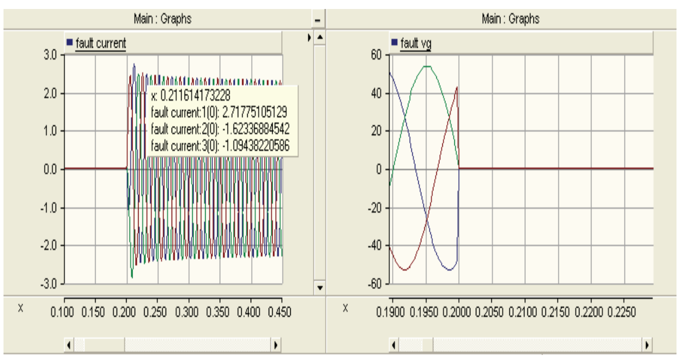

Fig. 4.Fault current and fault voltage

In the PSCAD simulator, a symmetrical three phase fault is applied on the secondary side of the transformer at 0.2 sec. The current and the voltage at the fault points are shown in the graphs. From the graph it is observed that, the maximum fault current that flows in the faulted path is 2.717p.u., which closely matches with the theoretical value obtained in Equation 2. It is also observed from Fig. 4 that, the value of voltage when the fault occurs is zero.

Case Study 2: In this case study, a network is considered where in, the synchronous generator (G) is loaded and the symmetrical three phase fault occurs at the motor terminals (M). The single line diagram is as shown in Fig.5:

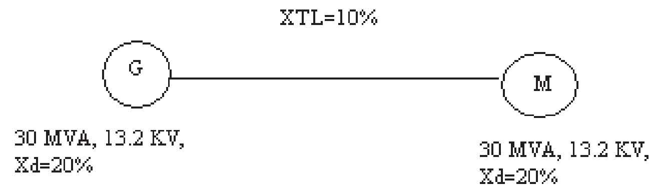

Fig. 5: Single Line Diagram

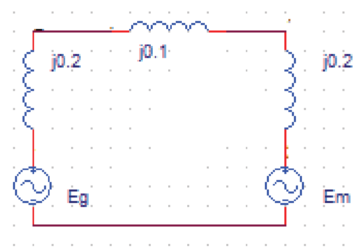

Fig. 6: Equivalent reactance diagram

The analysis is carried out as shown below:

Prefault voltage at fault point==0.97 p.u. ………. (3)

On occurrence of the fault, the equivalent circuit is as shown in Fig.7:

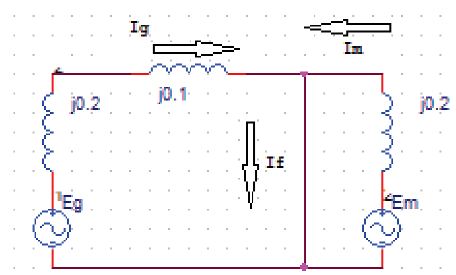

Fig.7: Equivalent circuit when fault occurs

Sub transient current in generator on occurrence of fault is, I_g=p.u. …………. (4)

Similarly, sub transient current in motor on occurrence of fault is, I_m=p.u. ……… (5)

And themagnitude of sub transient fault current is given as $|I_f|=|I_g|+|I_m|$=8.065p.u. ………………………………… (6)

The network simulated using PSCAD is as shown in Fig.8.

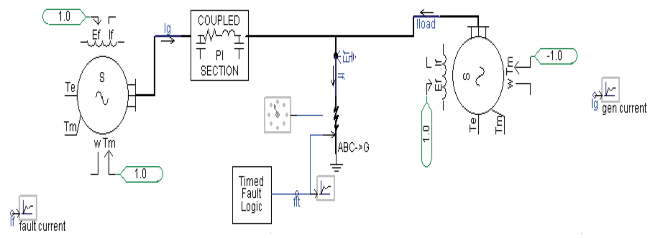

Fig.8: PSCAD network

The graphs for fault current and fault voltage are as in Fig. 9.

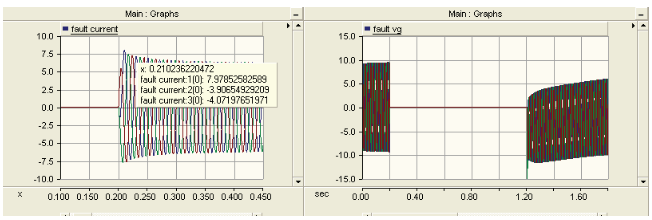

Fig.9: Graphs for Fault Current and Voltage

From the Fig. 9, we observe that, the magnitude of the fault current obtained is 7.97 p.u. which is close to the theoretical value obtainedas in Equation.6.

Unsymmetrical Faults

Any unsymmetrical fault causes unbalanced currents to flow in the system. Therefore unlike symmetrical fault analysis the system cannot be directly reduced to single phase system. The method of symmetrical components is used for the analysis and measurement of currents and voltages on occurrence of any unsymmetrical fault. The types of unsymmetrical faults that may occur in a power system are:

(i)Shunt type of fault - Single line to ground(LG) fault, Line to line (LL) fault, Double line to ground (LLG) fault.

(ii)Series type of fault – One conductor open fault, Two conductor open fault.

Shunt type of fault involves short circuit between conductors or between conductors and ground, whereas series type of are characterized by one or two conductors getting open while the other lines remain intact.

A network as shown in Fig. 10 is considered for analysis. A double line to ground fault is applied at F.

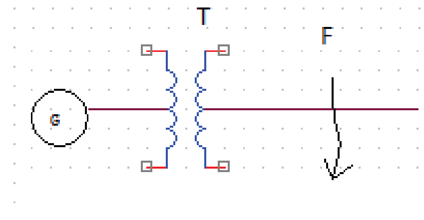

Fig.10: Single Line Diagram

For a double line to ground fault, the interconnection of the positive, negative and zero sequence networks is as shown in Fig. 11:

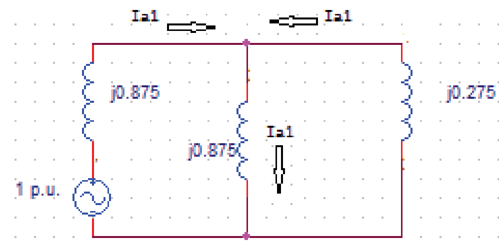

Fig.11: Interconnection of Sequence Networks

The fault current at fault point is, $|I_f| = 3*|I_{a0}| = 1.69$ p.u.……(7)

The simulated network is as shown in Fig.12 ,

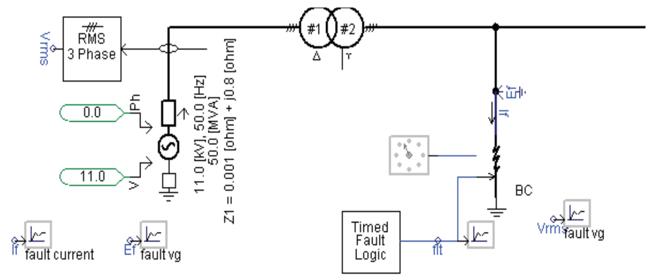

Fig. 12: PSCAD simulated network.

The graphs for fault current and fault voltage are as in Fig.13:

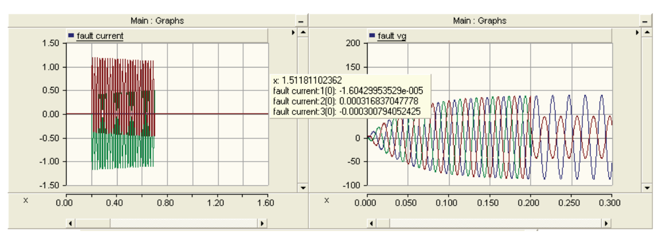

Fig.13: Graphs for double line to ground fault

From the graph we observe that the fault current as obtained by simulation is 1.604 p.u.

Also it is observed that, I_a=0, V_b=V_c, which are the conditions occurring when a double line to ground fault takes place.

The terminal voltage at generator is observed to be 1 p.u. under normal operating conditions and gets disturbed when a fault occurs at 0.2s as shown in Fig. 14. The fault persists till 0.7s. After the fault is cleared, the generator gets stabilized again with a value of 1 p.u.

From the results shown for different case studies, the students not only can validate the results obtained using equations but also they can get a feel of the situations in a practical power system network during the fault. It is also observed that mere use of equations do not illustrate post fault effects unlike the case with simulation.

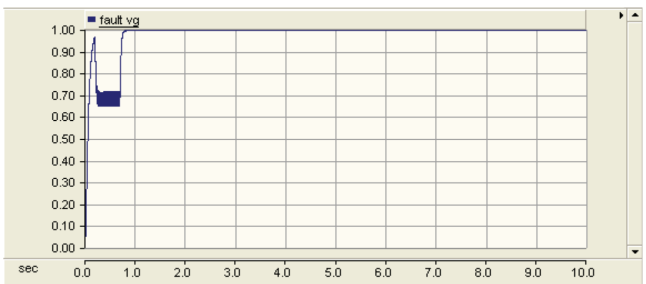

Fig.14: Terminal voltage of generator

From the examples illustrated in the previous paragraphs, a comparison between the two methods of teaching this particular course is carried out based on attainment of the program outcomes. The student will be able to achieve the following program outcomes without the use of PSCAD software.

(i) Apply knowledge of mathematics, science and engineering principles to the solution of electrical and allied engineering problems.
(ii) Formulate and analyze complex engineering problems using first principles of mathematics, science and engineering sciences.
(iii) Design solutions for complex engineering problems, and design system components that meet specific societal needs.

But with the introduction of PSCAD in the teaching-learning process, student will be able to achieve the additional program outcomes which are:
(iv)Design and conduct experiments and analyze and interpret data for complex systems.
(v) Select and apply appropriate modern engineering tools to complex engineering activities with an understanding of the limitations.
Following table is presented that gives summary of the coverage of program outcomes with and without use of PSCAD Software for problem solving and analysis.

TABLE 1: Summary of PO's addressed

Program Outcomes	**Without usage of PSCAD**	**With usage of PSCAD**
PO1:Engineering knowledge	√	√
PO2:Problem Analysis	√	√
PO3:Design/development of solutions	√	√
PO4:Conduct investigations of complex problems		√
PO5:Modern tool usage		√

CONCLUSION

In this paper, an effective method of teaching the PSA course using PSCAD software is proposed. As mentioned earlier, the laboratory courses are not conducted for the said subject. In the present method of teaching, the students solve the numerical manually by hand calculations. With the introduction of the proposed method of teaching, enhancement in the performance of the students can be expected as the student gets practical feel of the subject. Once the student gets familiarized and confidant with the usage of PSCAD, he/she gets motivated to take up larger/complicated electrical power systems for analysis. Also, rather than classroom solving of the problems, use of this tool helps in better understanding and analyzing capabilities of a student. The student can visualize the parameters such as voltage and current through graphs rather than simply obtaining a value through equation solving. This method of teaching also helps in attaining larger program outcomes.

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