



Application of APDL language in the switching power supply electromagnetic field analysis

Wei Zhang*¹ and Juanjuan Xing²

¹Faculty of Physics & Machinery and Electron Engineering, Xi'an University of Arts and Science, No. 168 Taibai South Road, Xi'an, China

²Xi'an International University- Institute of Engineering, Xi'an, China

ABSTRACT

This paper introduces the preparation of the electromagnetic field analysis with APDL language universal program steps and processes, for a typical Boost switch power circuit is given as an example to introduce how to model and post-processing analysis with universal program, The simulation results under ANSYS environment are compared with the simulation results under the MATLAB environment, the simulation results are basically the same in two kinds of different simulation environment, the universal program is an effective analysis method to analysis of the switching power supply electromagnetic field. APDL language has been used in switch power electromagnetic field analysis, one shorten analytical calculation time greatly and improve calculation accuracy, the other shortened the development cycle of the switching power supply and improved work efficiency, with a larger engineering practical significance.

Key words: Switching converter; Finite element; Electromagnetic field analysis; Universal program; APDL language

INTRODUCTION

Switching power supply is the development direction of high frequency, high reliability, low consumption, low noise, anti-jamming and modular. Some new power devices make the switch power supply capacity is growing. Application of some nonlinear power switch in switch power supply, On the one hand can enhance the frequency of the switching power supply, on the other hand, will increase the switching loss and increase the electromagnetic interference, So the switch power supply itself constitutes a major source of electromagnetic interference. This paper, Switching power supply's electromagnetic analysis was used the finite element ANSYS software as a platform [1-3].

ANSYS is a set of finite element analysis software can be used in various operating system, it has advantages such as strong function, good compatibility, convenient to use, fast calculation, and have been rapidly developed in recent years., and it is the preferred design engineer. Although the ANSYS Pre-processing and post-processing function is very powerful, but it can't solve some practical problems in the electromagnetic field of switch power supply, a finite element program need to develop specialized engineer.

One of the ways to solve these problems is to make full use of ANSYS Pre-processing and post-processing function, the electromagnetic field computation using independent programming. This method requires the use of ANSYS to provide the interface language -- APDL. APDL parametric design language (Ansys Parametric Design Language) is one of the advanced analysis technology, intelligent analysis method provides the user with a complex model, loading, solving and data processing functions, Can be used to realize the parameterized finite element analysis, analysis of batch processing, special analysis system two developments and design optimization [4-5]. Application of APDL script written by parametric modeling has the characteristics of intelligence analysis,

most of the work being done by automatically perform, which allows complex data input, modification is very convenient, but also provides a simple and efficient method for solving the problem, through careful design, users can create a highly efficient and flexible analysis scheme [7]. APDL features several techniques, including if - then - else branch, circulation etc. The relevant structural model was established based on APDL language, the model and load data into a finite element program developed by the required file format, and then return the result to the ANSYS for display.

METHOD OF APDL LANGUAGE PROGRAMMING WITH THE ANSYS SOFTWARE

APDL language program can be set to the specified functions, variables, which allows complex data input, the user to any design or analysis of property control, such as the size, material, load condition and mesh density. The APDL language provides parameters, array parameter, expressions and functions, branch and cycle, repeated and other functions, these functions can be used alone, also can be used at the same time [8-9].

For example, Structure for circulating language is:

*DO, Par, IVAL, FVAL, INC

*ENDDO

Among them, Par is used for loop variables, the whole process is: first to the loop variable Par value IVAL, then continuous cycle in each of the INAL to increase INC, if IVAL exceeds FVAL, circulatory arrest. INC default is 1, can also be a negative increment or non integer.

Another example, Structure array is defined as:

* DIM, Par, Type, IMAX, JMAX, KMAX,

Var1, Var2, Var3, CSYSID

Among them, Par is the parameter name; Type is an array type parameter's type, Including ARRAY (default), CHAR, TABLE and STRING. IMAX is the number of rows (for STRING arrays for the maximum number of characters allowed, ≤ 128); JMAX is the number of columns; KMAX is the surface; Var1~Var3 is used in the definition table array parameter, respectively is the row, column or the surface's label [10-11].

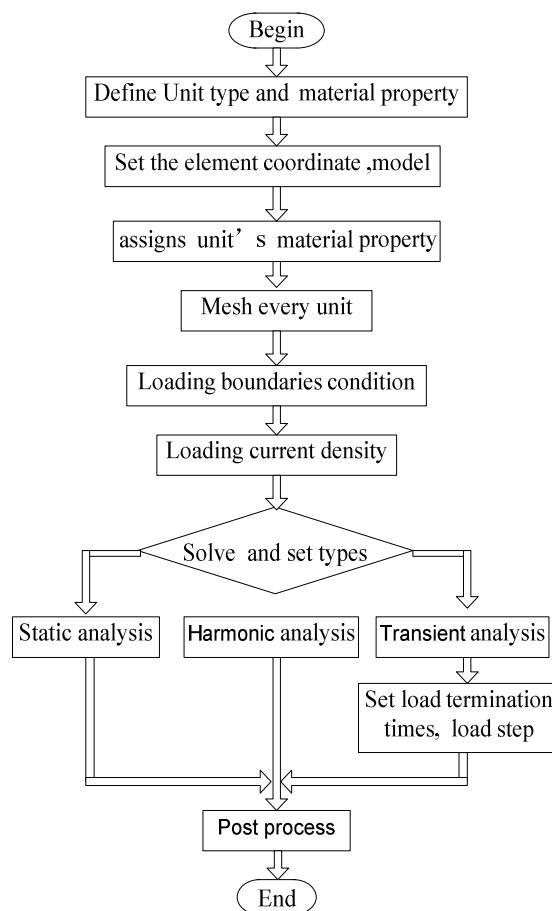


Fig.1: gram flow diagram

FLOW SIMULATION SOFTWARE

Using APDL program language and macro organization management analysis of ANSYS finite element command, Can display the realization of parametric modeling, parameterized loading and solution as well as the parameters of the processing results, the whole process so as to realize the parameterized finite element analysis, which is also the highest technology ANSYS batch analysis. To analysis several designs of various sizes, different load or serial products repeatedly parameters in the process of parametric analysis can simply modify , greatly improve the analysis efficiency, reduce the cost analysis. At the same time, finite element analysis program, users can use the APDL to develop the special, or write a function of small programs often repeated use, such as special loading macro, according to the specification strength or rigidity check macro etc. Flowing chart of the universal program as shown in figure 1.

1) Determining loading conditions

Need to explain in flow chart is: The boundary conditions of the load should be based on different circumstances, the applied load current density and voltage in two ways, usually by way of loading current density. The solution and the types of settings, if static analysis, if the choice of type of analysis can be directly solved, then post-processing; If the harmonic analysis, after the selection of the analysis type, set excitation the maximum amplitude and the excitation frequency, then it can be solved; If the transient analysis, after the selection of the analysis type ,need to set stop time and time step, and then to solve [12].

2) Paragraph writing for example

According to the characteristics of the object, the main purpose of this paper is to analyze the transient electromagnetic field. Following a small program fragment written in realization of this universal program:

```
/BATCH, LIST
KEYW, MAGEDG, 1    ! The specified field analysis
/PREP7             ! Into the pre processor
ET, 1, SOLID117    ! The specified element type
MP, MURX, 1, 1     ! Definition of material properties of air
MP, MURX, 3, 1     ! Definition of Material attributes of electrode
MP, RSVX, 3, 2.82e-8
CYLIND, 0.0005, 0, 0.01, 0.021, 0, 360,    ! build model
CYLIND, 0.0015, 0, 0.021, 0.032, 0, 360,
```

.....

Here is a brief introduction about the command stream of several basic words and its significance, of course it's statement is far more than these.

THE EXAMPLE ANALYSIS

1) Analysis object

The Boost circuit with simple structure as the object of analysis. The DC chopper circuit is the core of switching power supply and other power electronic switch circuit, Therefore the analysis of electromagnetic field distribution characteristics of the typical when the circuit works. The principle of the circuit as shown in figure 2:

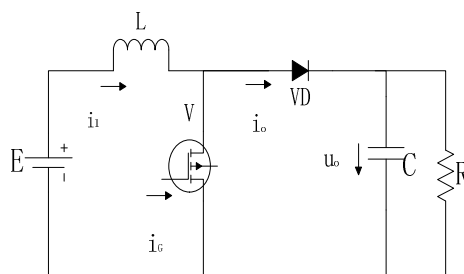


Fig. 2: Boost circuit schematics

Circuit in inductor current continuous and discontinuous two working modes. Using a full-controlled device V, Figure 2 used IGBT. VD is rectifier diode, the switching frequency $f = 125\text{KHz}$, duty cycle $D = 50\%$, $E = 100\text{V}$, $R = 50\Omega$, L with core inductor coil, coil turns $n = 100$ turns.

2) APDL parametric modeling

Each switch circuit is composed of the most basic components, which has certain function, according to different combinations of a switch circuit with different functions, so the first step for switching circuit modeling is the component modeling.

The core content of APDL language is a macro (Macro) and parameters (Parameter). The so-called macro (the suffix name for Mac) is a special function of the command combination, it is virtually a user program parametric. Which can be used as ANSYS's command processing, can have input parameters or not.

The following program fragment is a simple macro (name assumed macro file for RR.MAC), its role is to construct a resistance pattern as shown in figure 3.

```

/prep7                ! define the Analysis stage
/VIEW,1,1,1,1
/ANG,1
/REP,FAST            !Rotating coordinate system
cylind, 0.0015,0,0,0.011,0,360,
cylind, 0.0005,0,0,-0.011,0,360,
cylind, 0.0005,0,0.011,0.022,0,360,  !The definition of body 1~3
vglue, 1, 3
vglue, 1, 2          !Bonding operation on the body
finish              !This macro ends

```

Direct input RR in the command window, can be drawn as shown in Figure 3. The drawing process of other components such as capacitor, inductor, switch and so on are basically the same, do not make a detailed introduction. The other element is built corresponding macro, called when needed [13].

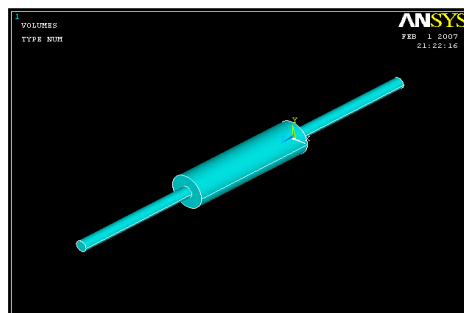


Fig.3: Resistor model generated by Macro File

The switch circuit components ANSYS model parametric modeling method as shown in Figure 4, the modeling process is as follows.

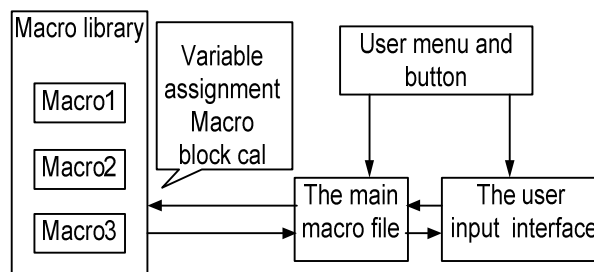


Fig.4: ANSYS parameterization modeling Structure diagram

(1) The establishment of a macro library

The quantities of macro to a text file, the formation of macro library, each macro block with a fixed ARG1 ~ ARG9 and AR10 ~ AR19 parameter definition of local input variables. These internal variables through the main macro file to assignment. In order to avoid changes in the object code, in the macro program files, try to use the component and assembly(Component) to define the line, plane, volume and other kinds of objects, for Boolean

operations, moving objects, copy editing, each macro block independent operation and combination of call compatibility.

(2) The establishment of the main macro file

The main macro file and user interaction is by using the MULTIPRO command customized various parameter input dialog box. Input the necessary parameters of the model, at the same time using the *DOWHILE process control block call macro statement in the library, parametric modeling of the components.

(3) Modify the ANSYS startup configuration file, custom user tools

When ANSYS10.0 is running, the program will in the default directory in the APDL to read the *.ans suffix for the configuration file, edit the file, the search path to add the /PSEARCH command to set the macro, add the *ABBR command button to customize the toolbar.

Complete parametric modeling, for not familiar with ANSYS users, only need to use a custom button to bring up the interactive input box, follow the prompts to enter the parts parameters, automatically generates switching circuit model of each component. Figure 5 is a switching circuit model and the unit automatically generated results.

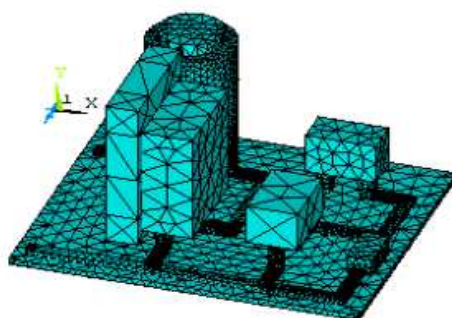


Fig.5: Finite element model of BOOST circuit

(4) Macro library flow diagram

Create a macro process as shown in Figure 6, according to the elements, analysis of type, different loading conditions and post processing, need to establish different types of libraries, usually need to establish material property database, circuit component library, create the load boundary conditions, loading a macro library, solving the macro library, the later is established post processing the macro, the general processes such as shown in Figure 6.

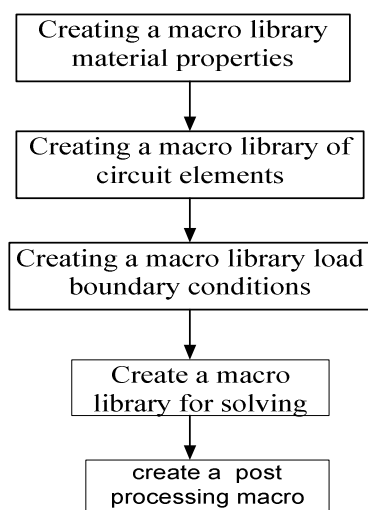


Fig.6: Flow Chart of Macro Libraries

(5) The main flow diagram

The finite element model of APDL parameter provides a powerful tool, APDL language has the basic variables and judgment cycle function. Using APDL language to achieve the whole device modeling, loading, solving, post process flow diagram is shown in figure 7.

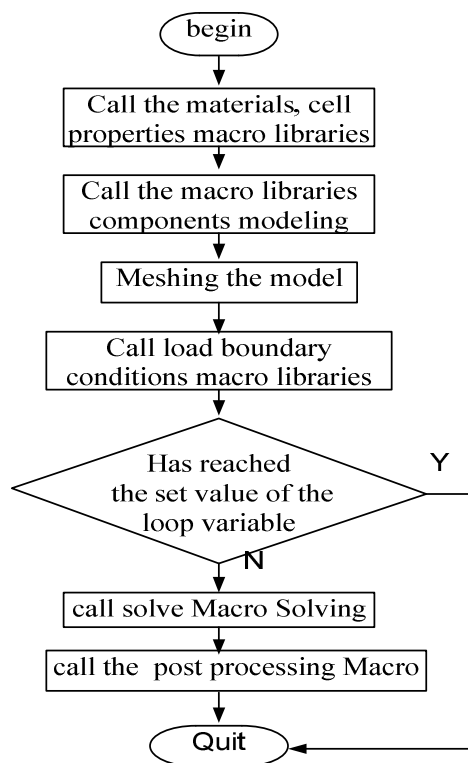


Fig.7: Flow Chart of Main Program

3) Simulation results

Figure 8 is a diagram of the simulation results of figure 5 electromagnetic field distribution, figure 9 is the current in the circuit inductance current and capacitor.

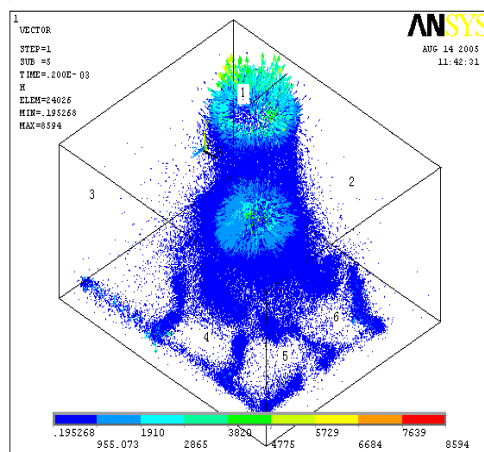


Fig.8: Distribution of magnetic field intensity

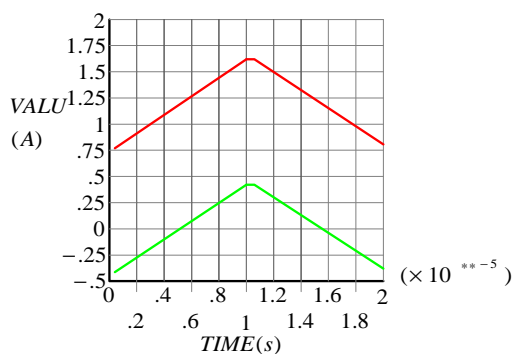


Fig.9: Distribution of magnetic capacitance current (lower) simulation waveform

EXPERIMENTAL VERIFICATION

The electromagnetic field calculation is more complex, here mainly uses the current can be calculated to verify. The same parameters in the MATLAB environment to establish the model shown in Figure 10, and the current as shown in Figure 11 waveform of inductance. The circuit simulation waveform of Figure 9 and the general program written in APDL language, can be seen both from the waveform waveform is basically the same.

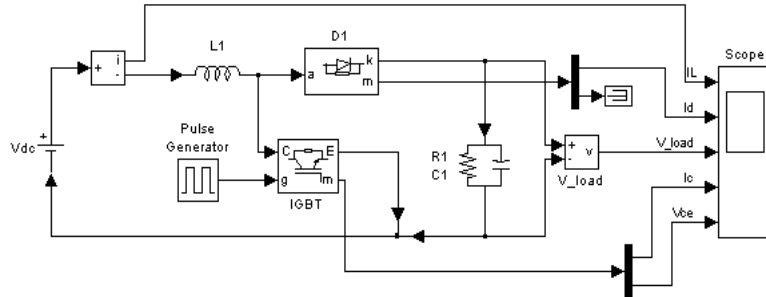


Fig.10:BOOST circuit simulation mode under MATLAB/simulink environment

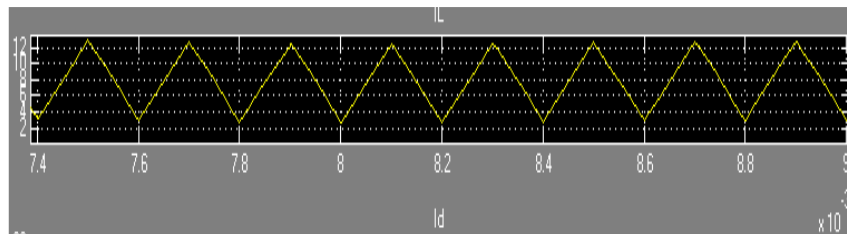


Fig. 11: The inductor current simulation waveform under MATLAB environment

From MATLAB simulation results in Figure 11 can get the inductor current incremental is:

$$\Delta i_L = \frac{13.3 - 4}{7.7 - 7.6} \times 10^3 = \frac{9.3}{0.1} \times 10^3 = 93000$$

From ANSYS simulation results in Figure 9 can get the inductor current incremental is:

$$\Delta i_L = \frac{1.68 - 0.75}{1 - 0} \times 10^5 = \frac{0.93}{1} \times 10^5 = 93000$$

From the calculating results, two kinds of simulation results are almost the same, indicating that uses the APDL language to the Boost converter model is correct, and effective.

ANALYSIS OF THE RESULTS

Using APDL language program only need to change the IGBT, the diode and the inductor and so on the original position, then the corresponding paste adhesive and other operations, can easily change the layout of the circuit. APDL is the foundation for ANSYS design optimization, Only establish processes to perform optimization on the design parameters of the parametric analysis, optimal design the target, and the simulation results verify the correctness of the general program modeling.

CONCLUSION

APDL language program, extend beyond the scope of traditional finite element analysis, provides the establishment of the standard parts library, sequence analysis, modify the design, design optimization and more advanced data processing ability. Not only can shorten the product design cycle, improve production efficiency, but also provides a shortcut to solve the problem of electromagnetic interference of the bridge circuit, with the practical values for engineering.

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