2021 IEEE 4th International Conference on Electronic Information and Communication Technology

A novel algorithm based on two-step CN-FDTD

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ABSTRACT

When studying the crosstalk of long-distance owerhead transmission lines, Finite Difference Time Domain (FDTD) method is limited by Courant Friedrichs Lewy (CFL) stability conditions. The improved method breaks through the limitation of CFL, but the accuracy can be reduced. This paper proposes a new high-precision method that breaks through the unconditional stability. By solving the transmission line equation, the electromagnetic field changes caused by the field-line crosstalk of the transmission line are directly solved. Combining the Crank-Nicolson (CN) difference method and the two step FDTD method, the two step Crank-Nicolson Finite Difference Time Domain algorithm (two-step CN-FDTD) is proposed. This algorithm is of great significance to the study of long-distance transmission line crosstalk because of its good adaptability and accuracy.

BACKGROUND

Nuclear explosion

Overhead power line system

Lightning

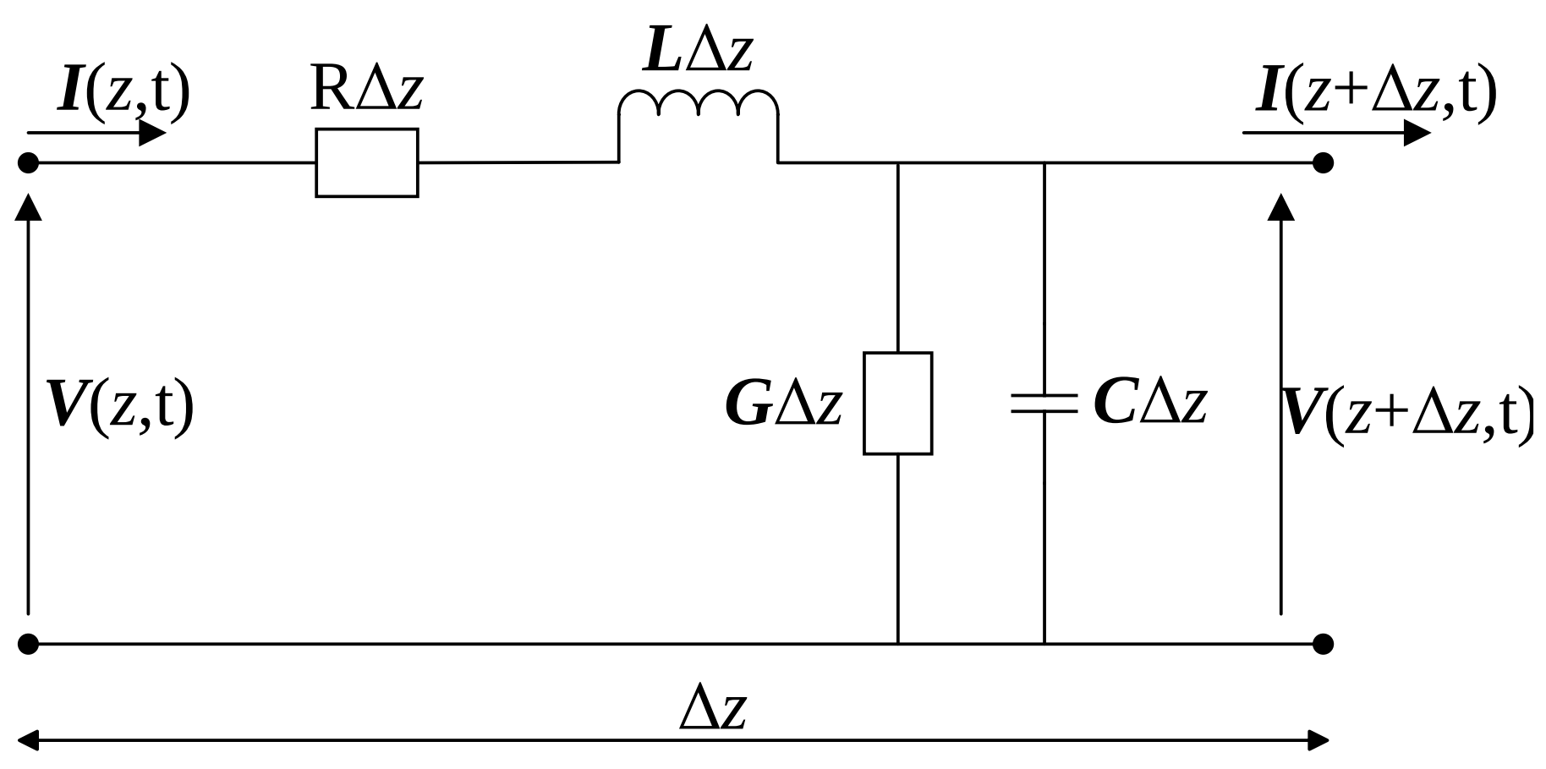
Substation switch tube

- ◆ Lightning and nuclear explosion
- ◆ Complex electromagnetic environment
- ◆ Substation switch tube

Electromagnetic Pulse

- ➢ Enter the cable to generate crosstalk to adjacent cables
- ➢ Make signal distortion, waveform distortion
- ➢ Performance and safety of electrical equipment

METHODS



Transmission line equation:

$$\frac{\partial V(z,t)}{\partial z} + RI(z,t) + L\frac{\partial I(z,t)}{\partial t} = 0 \quad (1)$$

$$\frac{\partial I(z,t)}{\partial z} + GV(z,t) + C\frac{\partial V(z,t)}{\partial t} = 0 \quad (2)$$

For the inter-coupling one-dimensional partial differential wave equation system, it is found that there will be a sharp attenuation of the signal in the process of solving using the pure implicit scheme after theoretical derivation and a large number of simulation experiments. Therefore, one time iteration step is divided into two time steps evenly.

The iterative equation of the voltage current is obtained according to the time period of n n + 1/2 and N + 1/2-N + 1.

According to the n ⟶ n + 1/2 and n + 1/2 ⟶ n + 1 two time periods, the iterative equation is obtained.

$$V_k^{n+1/2} = Cva \times V_k^n - Cvb \times \left[I_{k+1/2}^{n+1/2} - I_{k-1/2}^{n+1/2} \right] - Cvb \times \left[I_{k+1/2}^{n} - I_{k-1/2}^{n} \right] \quad (3) \qquad Cva = \frac{1 - G\vartriangle t/4C}{1 + G\vartriangle t/4C}$$

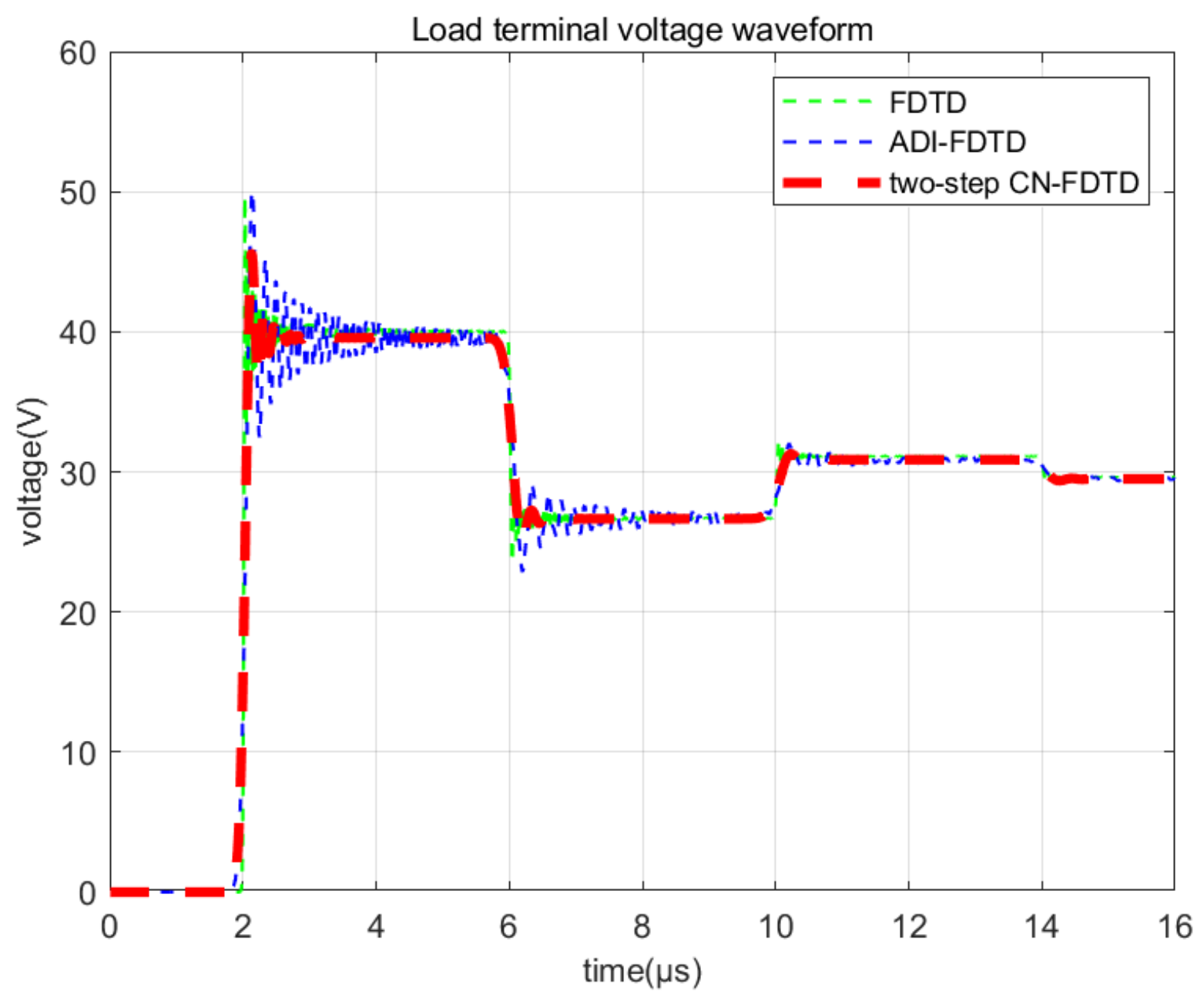
$$I_{k+1/2}^{n+1/2} = Cia \times I_{k+1/2}^{n} - Cib \times \left[V_{k+1}^{n+1/2} - V_k^{n+1/2} \right] - Cib \times \left[V_{k+1}^{n} - V_k^{n} \right] \quad (4) \qquad Cvb = \frac{\vartriangle t/4C\Delta z}{1 + G\vartriangle t/4C}$$

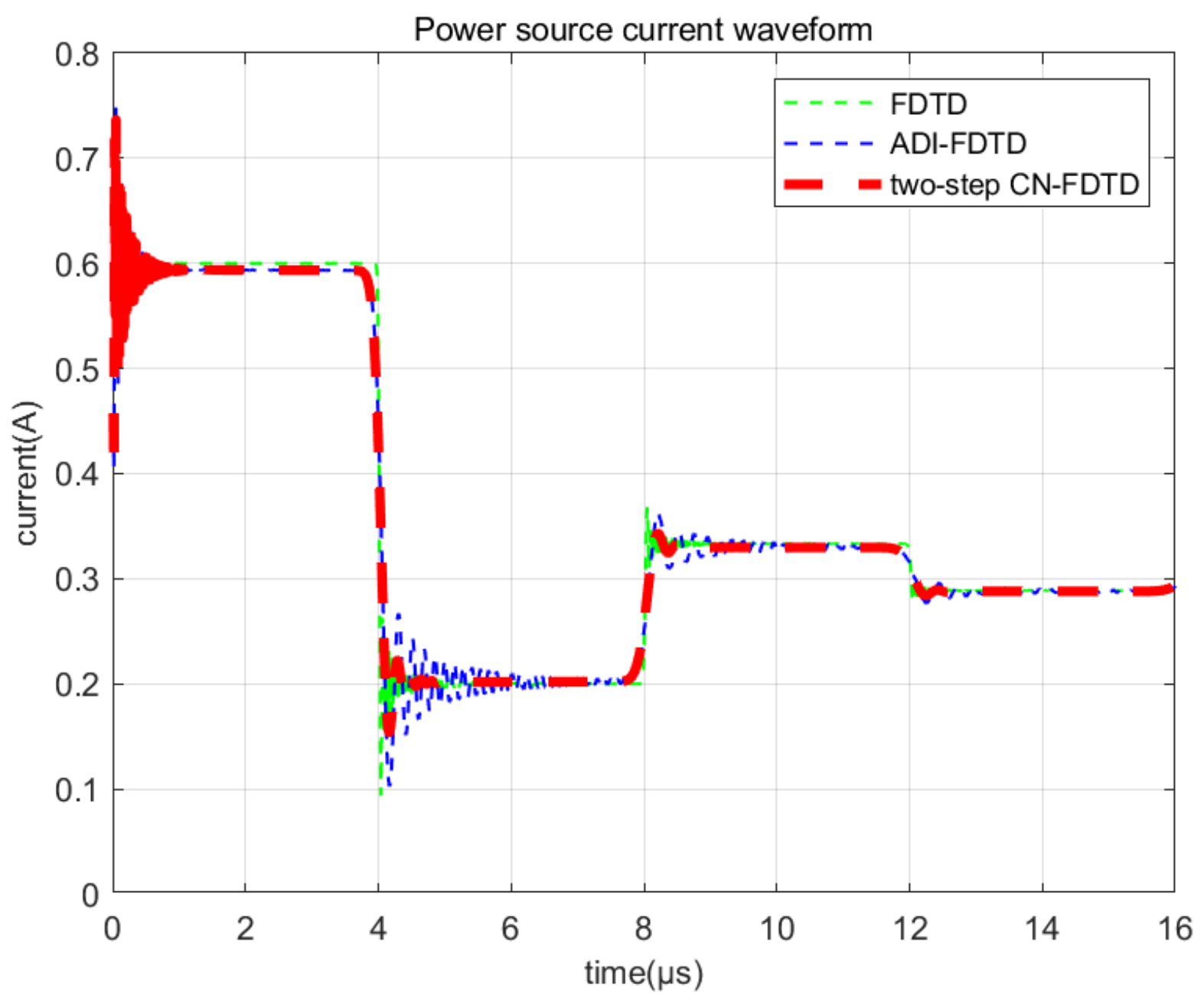
$$V_k^{n+1} = Cva \times V_k^{n+1/2} - Cvb \times \left[I_{k+1/2}^{n+1} - I_{k-1/2}^{n+1} \right] - Cvb \times \left[I_{k+1/2}^{n+1/2} - I_{k-1/2}^{n+1/2} \right] \quad (5) \qquad Cia = \frac{1 - R\vartriangle t/4L}{1 + R\vartriangle t/4L}$$

$$I_{k+1/2}^{n+1} = Cia \times I_{k+1/2}^{n+1/2} - Cib \times \left[V_{k+1}^{n+1} - V_k^{n+1} \right] - Cib \times \left[V_{k+1}^{n+1/2} - V_k^{n+1/2} \right] \quad (6) \qquad Cib = \frac{\vartriangle t/4L\vartriangle z}{1 + R\vartriangle t/4L}$$

RESULTS

1. An ideal double conductor transmission line verification



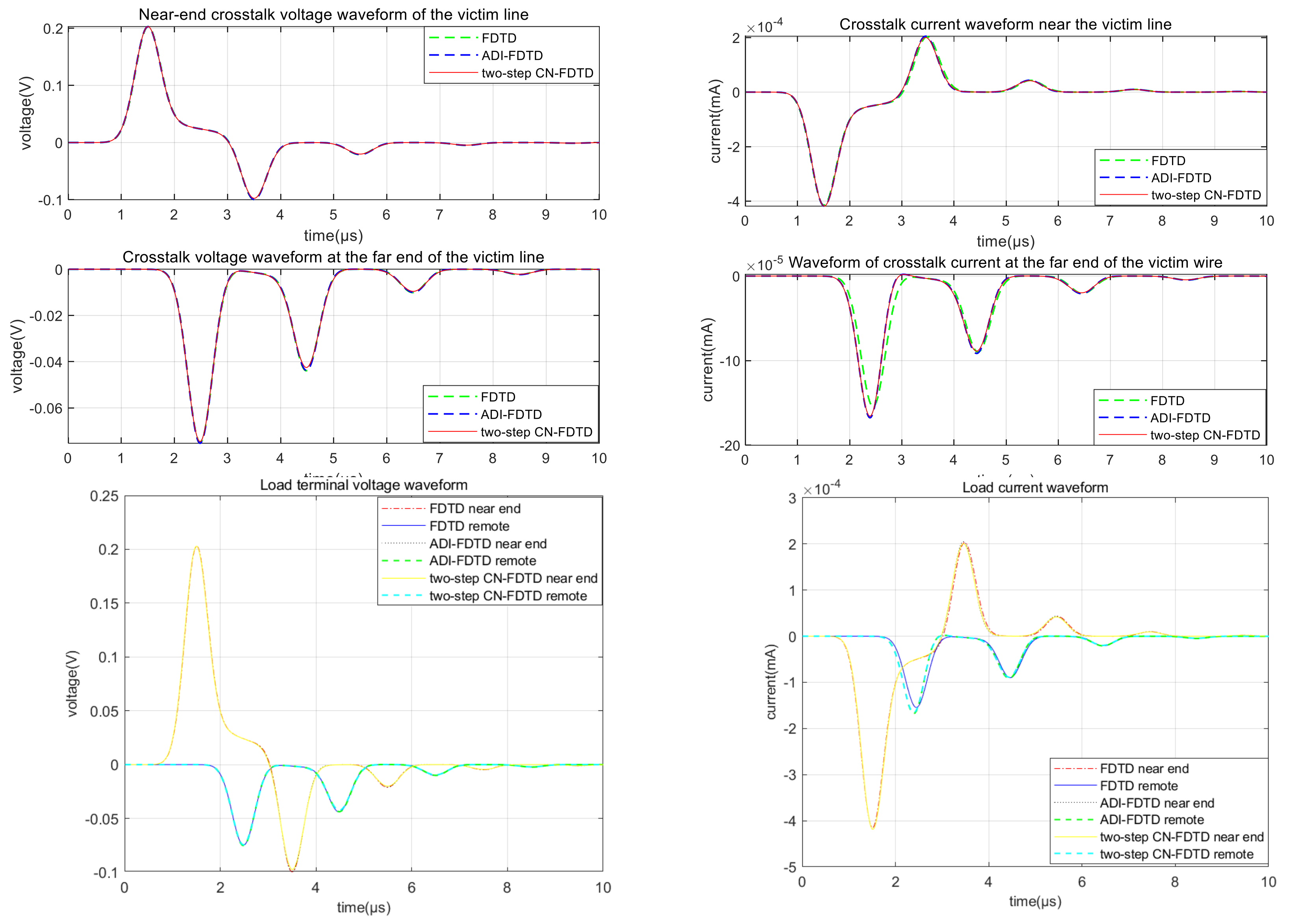


RESULTS

model	Two-conductor step signal model		
method	*FDTD*	*ADI-FDTD*	*two-step CN-FDTD*
time/s	0.805	0.353	0.154

It can be seen from Table that the simulation time of the two-step CN-FDTD of the same model is 5 times shorter than that of the FDTD and 2 times shorter than that of the ADI-FDTD .

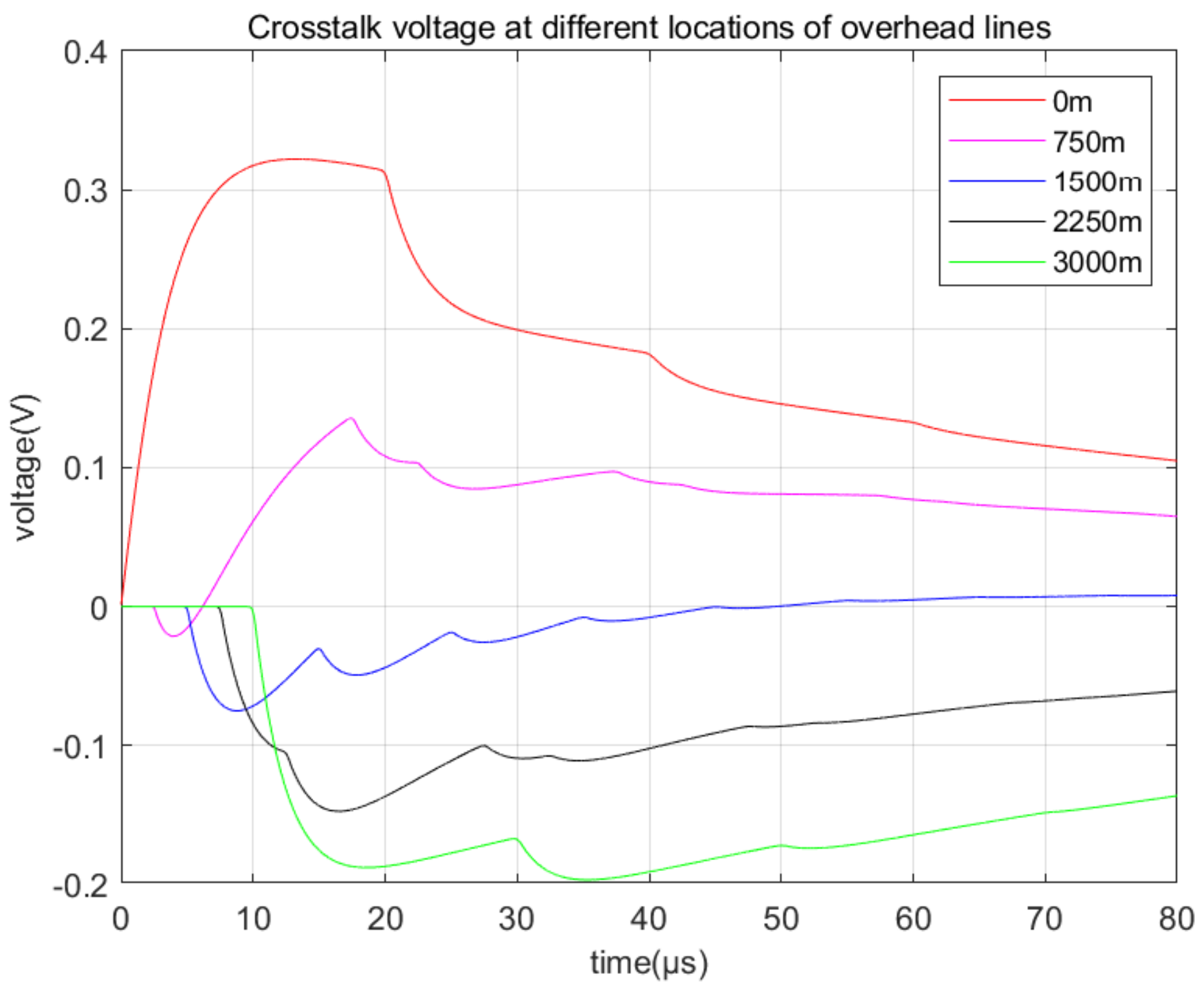
2. Multi-conductor overhead lineverification



The two-step CN-FDTD and the ADI-FDTD, FDTD curve fits well, and the crosstalk error is less than 1%, but the space step and time step of the two-step CN-FDTD and ADI-FDTD are selected larger. The simulation time is shorter and the efficiency is higher.

model	Multi-conductor Gaussian signal model		
method	*FDTD*	*ADI-FDTD*	*two-step CN-FDTD*
time/s	1.456	0.628	0.683

It can be seen from Table that the simulation time of the TWO-STEP CN-FDTD of the same model is 2 times shorter than that of the FDTD. For longer-distance overhead lines, the number of grids divided by the FDTD will increase sharply, reducing computational efficiency.



It can be seen from the figure that the near-end crosstalk amplitude of a long-distance overhead multi-conductor transmission line is the largest. As time and distance change, the crosstalk voltage gradually decreases. This is due to the distortion and attenuation of the voltage waveform caused by the loss of the metal wire itself and the loss of the ground impedance caused by the limited ground conductivity.

CONCLUSIONS

In this paper, the FDTD will be restricted by the stability conditions of CFL, leading to the problem of large calculation amount and low calculation efficiency in the process of long-distance transmission line simulation, and the unconditionally stable two-step CN-FDTD is used to solve the problem. The TWO-STEP CN-FDTD can choose the advantages of larger time step and space step, which is very suitable for the simulation calculation of long-distance overhead wire beam crosstalk. Therefore, within the acceptable crosstalk error range, this method greatly reduces the simulation time, and the calculation efficiency is improved. The high-precision method proposed in this paper has important reference significance for the research of long-distance transmission lines.

ACKNOWLEDGEMENNTS

This paper was supported by ‘Key Laboratory of Advanced Ship Communication and Information Technology’ of Ministry of Industry and Information Technology Harbin Engineering University.