Modeling for Power Supply Substation in Maglev Train System

Yun-Seong Lee and Jin-O Kim
Dept. of Electrical Engineering, Hanyang Univ., Seoul, Korea
lypd@hanyang.ac.kr, Jokim@hanyang.ac.kr

HyungChul Kim
Electric Power Supply Research Division, Korea Railroad Research Institute, Uiwang, Korea
hckim@krri.re.kr

ABSTRACT: Since a power supply substation of the magnetic levitation train system includes an inverter which is necessary to change the frequency of power, it has a different characteristic comparing to any other railway system. Nowadays, a study is undergoing to determine rating of facilities constituting a power supply system and modeling that system. This paper proposes an analysis model for the power supply system of the magnetic levitation train using the 3-level inverter. Also, the analysis for output characteristic is performed using the PSCAD/EMTDC program. The control method about the output of 3-level inverter is also described for supplying power to the loads in magnetic levitation train system.

1 INTRODUCTION

Nowadays, a study is undergoing to determine rating of facilities constituting a power supply system and modeling that system. The study for the power supply system is essential because that is a core system for operating the train system and supplying power to train loads [1]. The power supply system of Maglev train should be also analyzed to identify the power supply procedure. Since a power supply substation of the magnetic levitation train system includes an inverter which is necessary to change the frequency of power, it has a different characteristic comparing to any other railway system. In this paper, the power supply system of Maglev trains is modeled using a 3-level inverter, and the output characteristic is analyzed by the PSCAD/EMTDC program. The control method about the output of 3-level inverter is also described for supplying power to the loads in magnetic levitation train system.

For the simulation, the Transrapid Maglev train system is analyzed. In case of Transrapid-08 operated in Shanghai, China, the power supply system includes a main substation, a propulsion substation and a auxiliary substation. The main substation converts 110 kV power received from a distribution network to 20kV power, and supplies that power to the propulsion substation and the auxiliary substation. The propulsion substation receives 20kV power from the main substation and transforms power for a level to propel the trains. The auxiliary substation has a role which transforms power to supply to a switch station, a control center, a maintenance station and so on [2]. The whole system organization and facility rating are determined by Transrapid-07 system [3], and this paper refers Transrapid-08 system in Shanghai for analyzing the structure of inverter [4].

2 POEWR SUPPLY SYSTEM

2.1 Structure of Power Supply System

The structure of power supply system is depicted in Figure 1. In Figure 1, the circuit diagram of Transrapid-07 is presented simply and it would be enlarged as shown in Figure 2 [3]. Considering Korean power system, the main substation receives 154kV power from the distribution network, and transforms to 22.9kV power and then 22.9 kV power is converted once again to rectifier option voltage through a rectifier input transformer.

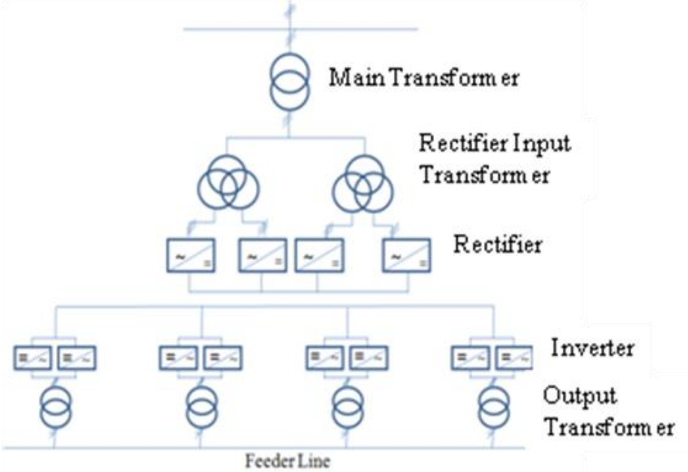

Figure 1. Power supply system.

The converted alternating current voltage is transformed to a direct current voltage through the rectifiers, and that voltage is set to input voltage of 3-level inverters. The inverters control the voltage and frequency for the designed output.

Finally, 3-phase output from the inverters is supplied to the loads with the last voltage transform through a output transformer.

In Figure 1, the rating of main transformer, rectifier input transformer and output transformer are 31.5MVA, 2 x 5.6MVA and 4 x 1.8MVA respectively. The phase voltage magnitude of output transformer is under 4,500V with transrapid-07 and frequency range changes to maximum of 215Hz [3]. The 3-level inverter is composed of GTO(Gate Turn-Off) thyristors [4].

2.2 3-level Inverter

The 3-level inverter operates to output the high-voltage, medium-voltage and low-voltage through switch's on/off operation and two capacitors connected as series [5].

The 3-level inverter has a advantage that output voltage has a low distortion relatively due to many steps of output voltage pulse. The 3-level inverter has a half-voltage hanged to switching component than the 2-level inverter, so that it could be applied to high-voltage system and high-power structure easily. The loss of 3-level inverter is low because it has low-voltage hanged to components relatively, thus it is advantageous for a high frequency switching.

If the high frequency switching is materialized using 3-level inverter, the system operator gains the decrease of harmonic wave and noise [6].

3 MAGLEV POWER SUPPLY SYSTEM MODEDING

In this paper, the Maglev power supply system based on Transrapid-07 is modeled using PSCAD/EMTDC [3]. The whole system organization and facility rating are determined by Transrapid-07 system, and the bus voltage would be converted to 22.9kV from 154kV through the main transformer considering Korea power system environment.

The PSCAD model is depicted in Figure 3. In Figure 3, the circuit diagram includes a main transformer, two rectifier input transformers, two rectifiers, two 3-level inverters and an output transformer.

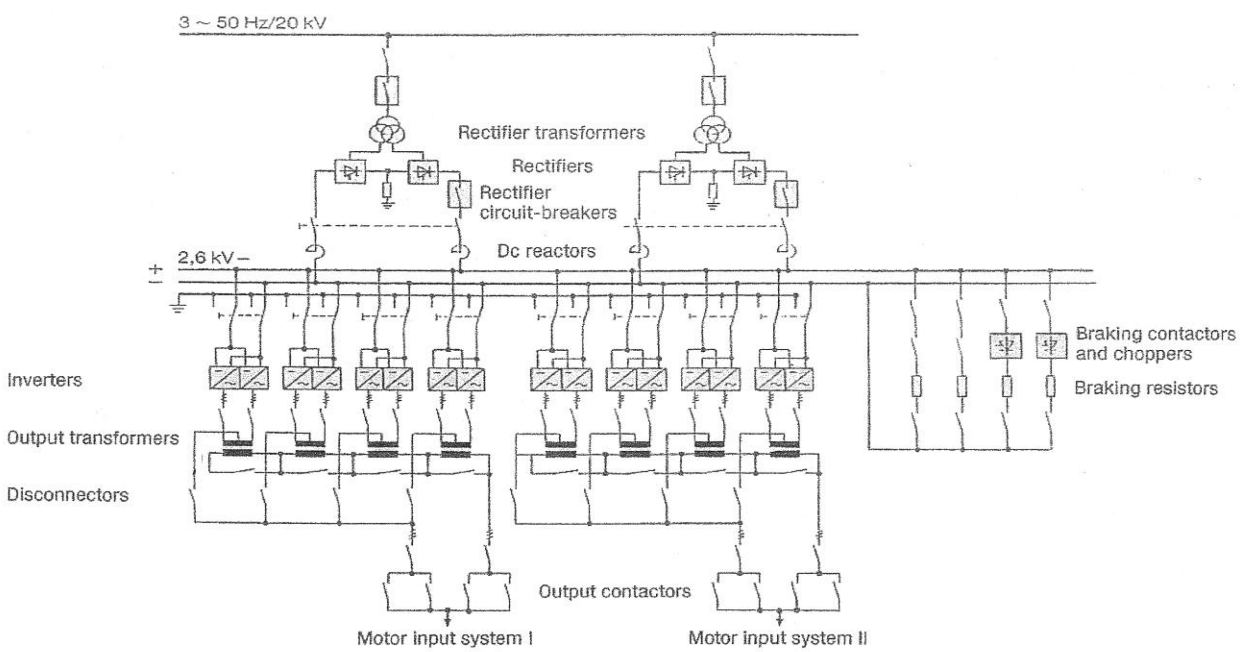

Figure 2. Power supply system for Transrapid 07[2].

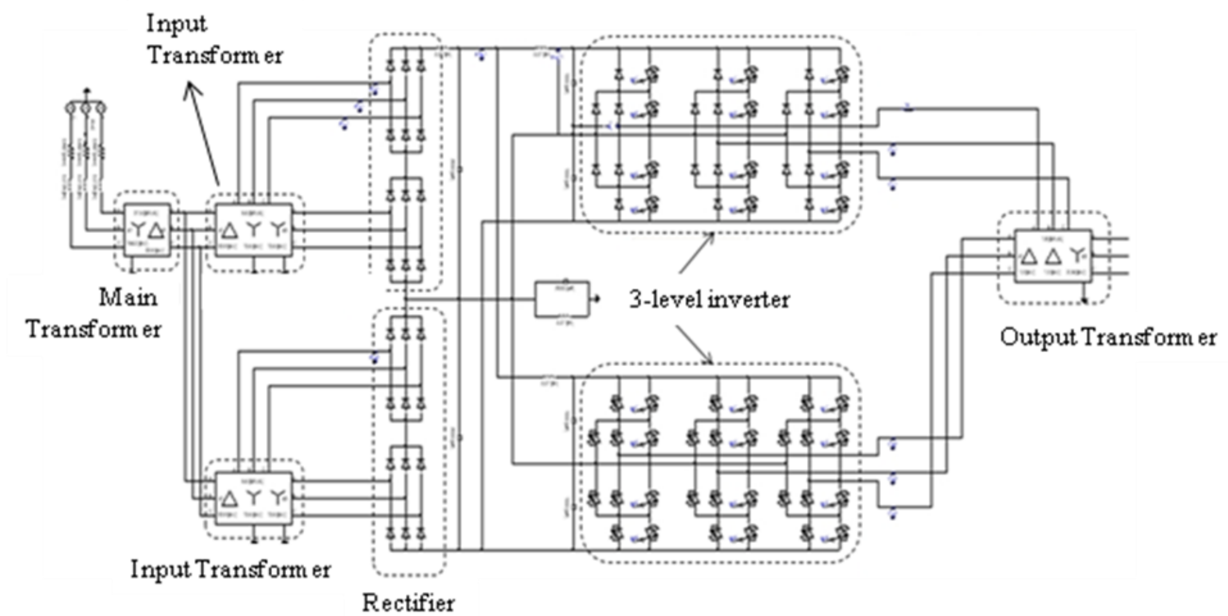

Figure 3. Modeling of power supply system using PSCAD/EMTDC

From view point of whole structure, two substations as Figure 1 are connected to both ends of line, and one substation is composed of a main transformer, two rectifier input transformers, two rectifiers, eight 3-level inverters and four output transformers.

For setting the rating of facilities, the rectifier input voltage is initialized as 1kV, and then rating of input transformer is determined according to that rectifier input voltage. As switching component of 3-level inverter, GTO thyristors are used [2]. The output voltage of the 3-level inverter would be converted through output transformer to fit designed voltage which is supplied to loads. Therefore, the rating of the output transformer should be determined according to voltage level of loads.

The thyristor gate signals of the 3-level inverter are generated by comparing between two carrier waves and a standard wave. A limitation of GTO's switching frequency is 400Hz approximately. Accordingly, the power supplying as the maximum frequency of Transrapid-07, 215Hz, could be performed.

The standard wave and two carrier waves are showed as Figure 4.

By using existing studies related power electronics [8], the thyristor gate signals are generated, and showed as Figure 4.

As stated above, each switch could be turned on or off by comparing the magnitude between carrier waves and standard wave, and then those switch operations derive gate signals. The modulation rate of standard wave and initial frequency are set as 0.7 and 60Hz respectively. The frequency of carrier waves is initialized as 660Hz.

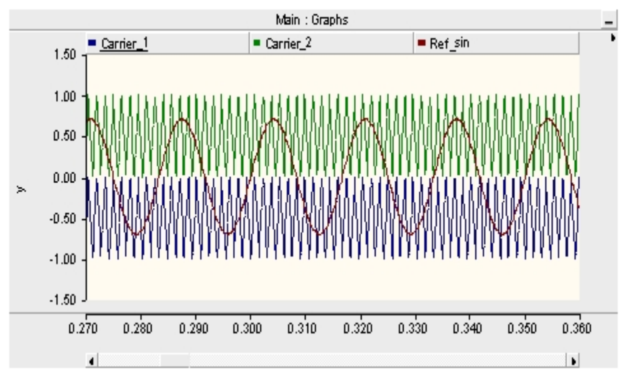

Figure 4. Waveform of standard wave and carrier waves

The load is set as a 13.6MW of inductive load which has an equal magnitude with the maximum active power of Transrapid-08 [7].

Under the condition as stated above, the simulation is performed, and 3-phase voltages of 3-level inverter are showed in Figure 5.

In Figure 5, the peak value of inverter output wave is 1kV, which presents DC input voltage, and its width is controlled by modulation rate. The frequency of inverter output wave has a same value with that of the standard.

The shape of phase voltage waves are presented as three step(1kV, 0V, -1kV) reflecting the inverter's output characteristic.

The line-to-line voltage of inverter output is showed in Figure 6, and Figure 7 is the output voltage wave of the output transformer according to frequency variation of standard wave.

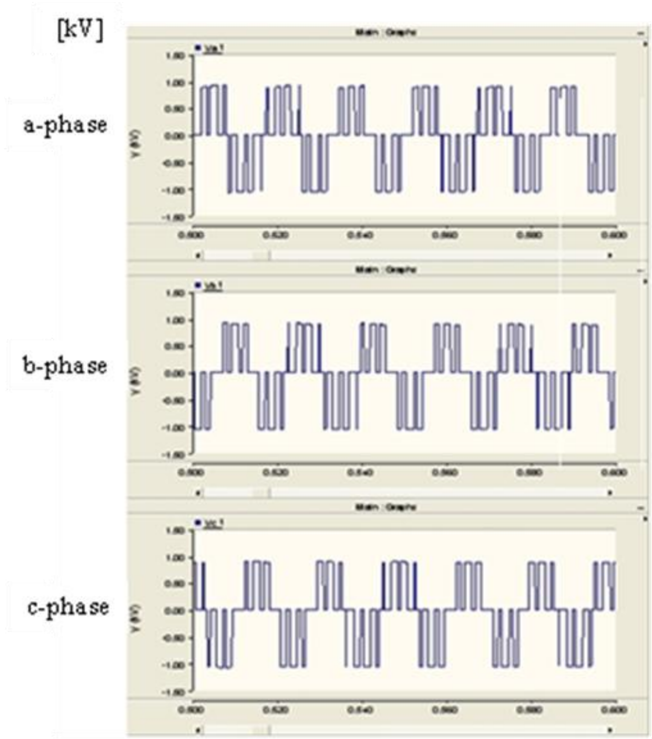

Figure 5. Waveform of phase voltages for inverter output

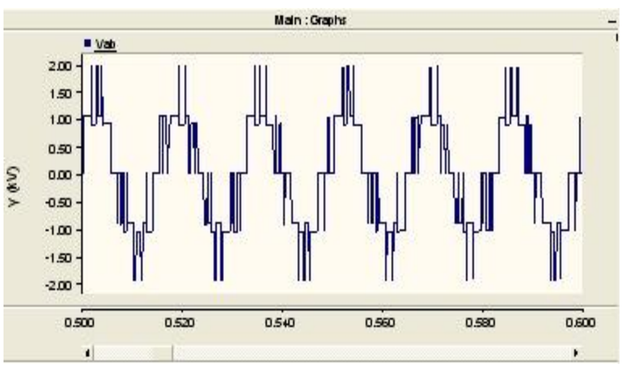

Figure 6. Waveform of Line-to-Line voltage for inverter output

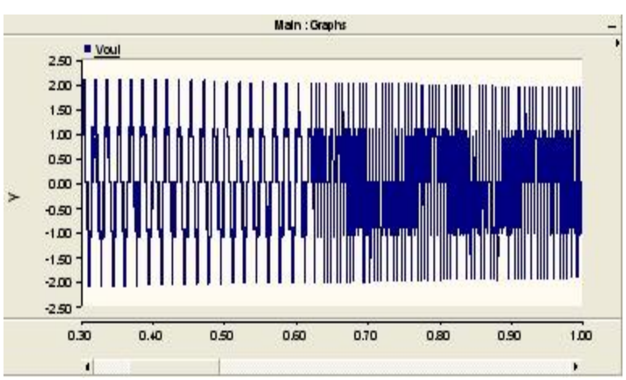

Figure 7. Output voltage wave of output transformer according to frequency variation of standard wave.

Keeping modulation rate as 0.7, the frequency of standard wave was changed from 60Hz(initial frequency) to 215Hz(maximum frequency) at 0.6 second in figure 7. Consequently, the output voltage frequency of the output transformer was changed to 215Hz at 0.6 second as shown in Figure 7.

In Figure 8, the result for output voltage of output transformer is showed when the modulation rate is changed 0.7 to 0.35 with 60Hz of the standard wave frequency. The amplitude of output wave was changed to half due to the modulation variation.

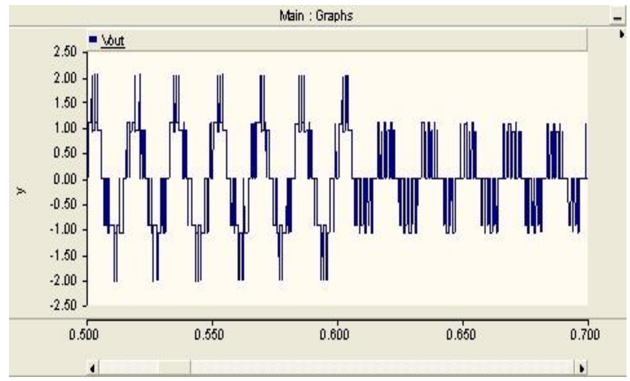

Figure 8. Output voltage for modulation variation of standard wave

4 CONCLUSIONS

This paper presents the analysis model for the power supply system of the magnetic levitation train using PSCAC/EMTDC. The whole system organization and facility rating are determined by Transrapid-07 system, and this paper refers Transrapid-08 system in Shanghai for analyzing the structure of inverter. The control method for the output of 3-level inverter is also described for supplying power to the loads in magnetic levitation train system.

In case of Transrapid-08, the substation includes a main transformer, two rectifier input transformers, two rectifiers, two 3-level inverters and an output transformer. Using the rating of those facilities and inductive loads, the simulation is performed.

Additional studied such as facilities rating, transformer output analysis, harmonic filter, wave distortion should be carried out based on this study.

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