Analysis of Signals Characterization of Circuits on the Traction Power Systems

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Abstract：In this paper present the characteristics of the signals and ripple harmonics in the circuits of the traction power systems of the Taipei mass rapid transit system. This analysis provides a novel simulation method, using Matlab software program application to the signals and ripple and harmonics simulate. This investigation uses a reality circuits and systems to simulate the DC traction power system operation for the Taipei metro systems. The analyses discover that the ripple harmonics and operation waveform affect the circuits of the power system design, feature and regulation, and influence on the operation stability of the DC-link between the traction power and vehicle propulsion systems. The simulation data can observe the typical harmonic characteristics for the behavior of the DC traction power systems. This study reveals the running waveforms of the traction power rectifier and vehicle propulsion system operation that can be precise control and regulation. This analysis results of the characteristic of the operation waveform and ripple harmonics in the DC link systems can help engineers to identify system design and after maintenance regulation.

Keywords: harmonics, ripple, inverter, converter, DC link, traction power system.

1 Introduction

ABBREVIATION：

BBS	Bulk Supply Substation
DC	Direct Current
DM	Driver Room
GTO	Gate Turn-Off
IGBT	Insulation Gate Bipolar Transistor
KPH	Kilometers Per Hour
TSS	Traction Supply System
PWM	Pulse-Width Modulation
TMRTS	Taipei Mass Rapid Transit Systems
T	Trailer
VVVF	Variable-Voltage Variable Frequency

The circuit of the traction power system of the TMRTS is provided the 750dcV to third rail and supplies the train running power system. The power is supplied from Taipower's BBS were 3 ϕ, 60Hz and 161/22kV; and then fed to the traction supply substations TSS with 22kV via two zig-zag rectifier transformers. The zig-zag windings allow the [i]phase of the primary voltage to be shifted by +7.5° or –7.5°. All TSSs were originally equipped with two 12-plus converter units to parallel connect 24-plus supply 750V dc through the third rail to the trains as shows in Fig.1. The railroad tracks as the return path for the loading current [1-4].

The running rails are not only used as the traction power return current path but also carry signaling for he operation control of cab signals. Therefore, the railroad includes controls signals, propulsion power, harmonics, and other electromagnetic noise. These signals may be compatible or may interfere with each other. Due to the complexity on the real system, the simulation method uses practical information which is presuming parameter to put on the circuits. This paper will present the results of the ripple harmonic in DC link between the traction power and vehicle propulsion systems on

TMRTS. In this paper, we describe a new simulation technique that can applied for analyzing the characteristics of ripple harmonics in the DC traction power of the MRT system. With regard to the MRT and railway systems, although the AC harmonics have been discussed previously, very few studies have conducted research and discussed DC ripple harmonics.

This paper is organized as follows. Section 1 explained standard abbreviation and introduces this article content. Section 2 introduces the layout of the traction power supply system. Section 3 introduces rectifier theories. Section 4 introduces inverter. Section 5 describes circuits and system simulation and presents a novel dc harmonic analysis method and simulation result for the harmonics of the DC link ripple. Section 6 discussed this paper conclusion. The value of the dc harmonics of the ripple on the DC link of the TMRTS is performed under simulations. Moreover, this work reports the analysis and characterization of the DC ripple harmonics of the TMRTS. Conclusions are finally drawn in the last section.

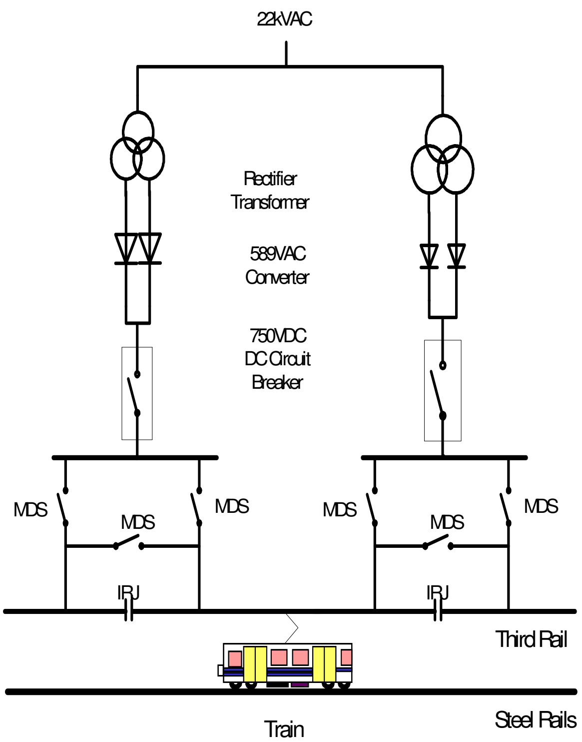


Fig. 1. Power system frame drawing of Taipei TMRTS.

2 Layout of Traction Power Supply System

The circuit of the traction power supply system is supplies from 161kV Taipower transmission lines to BSS with 161kV/22kV. The 22kV ac power of the TSS with 22kV/589V comes from the low-tension side of the BSS, via power cables illustrated as Fig. 2. TSS includes two transformers with three phases to six phases winging, to convert ac power from 22kV to 589V; the primary winding is in △ connections and the secondary winding is in △ and Y connections. Fig. 2 shows the two transformers with two parallel 12-pulse rectifiers are used in parallel to form a 24-pulse rectifier unit. The primary winding does not include a phase shift. The two secondary windings have phase shifts of –7.5° and +22.5° and of +7.5° and -22.5° as shows in Fig. 3, respectively. They are combined to yield a phase shift of 15°, and are fed to the two parallel 12-pulse rectifiers, to supply 24-pulse 750V dc traction power.

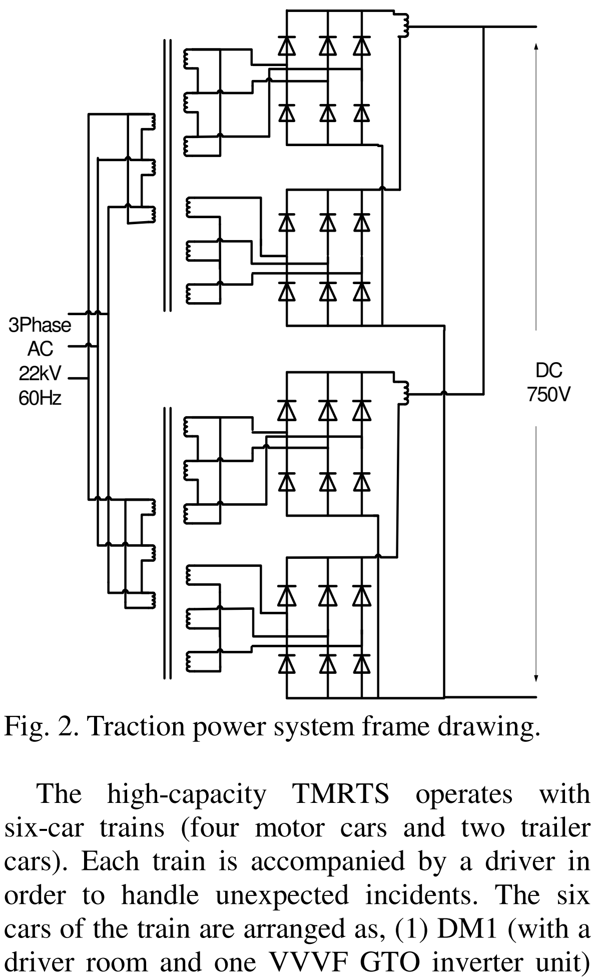


Fig. 2. Traction power system frame drawing.

The high-capacity TMRTS operates with six-car trains (four motor cars and two trailer cars). Each train is accompanied by a driver in order to handle unexpected incidents. The six cars of the train are arranged as, (1) DM1 (with a driver room and one VVVF GTO inverter unit) (2) T (trailer) (3) M2 (with one VVVF GTO inverter unit) (4) M2 (5) T and (6) DM1. In summary, each train includes two driver rooms (DM1), four inverter units (DM1 and DM2), and sixteen induction motors (DM1 and M2). Table 1 lists the ratings of the motor used in the TMRTS including 3 types. A car (DM1 and DM2) has four 200Hp three-phase induction motors, driven by two VVVF GTO inverters as shown in Fig. 4.

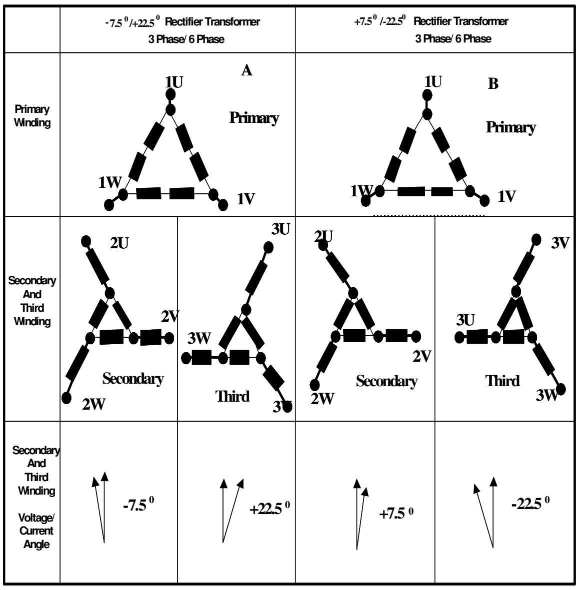


Fig. 3. Traction power rectifier transformer frame drawing.

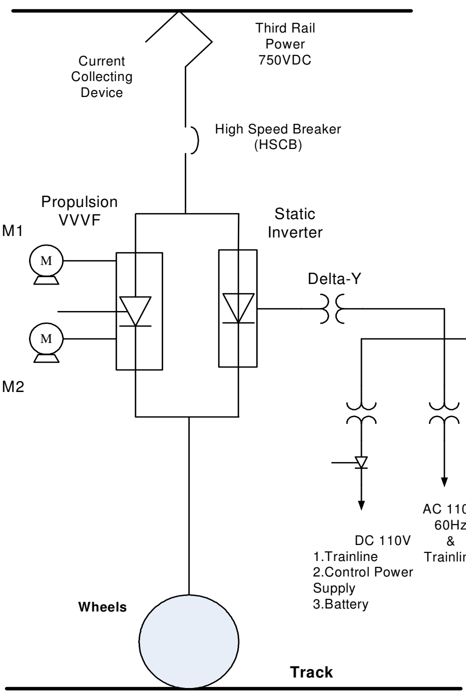


Fig. 4. Train propulsion system frame drawing.

Table 1. Ratings of the driving motors

Types	Inverter	Voltage (AC)	Speed (rpm)	Power (kW)	Gear-ratio	Control frequency
1	GTO	507	1658	147	6.6667	0~133Hz
2	GTO	478	2050	230	6.8125	0~133Hz
3	IGBT	550	1801	175	6.3131	0~133Hz

Table 2 lists the half-wave rectifier phase parameters including phase numbers of 6, 12, 24, and 36 to the corresponding rectification phase angles of 60°, 30°, 15°, and 10°, frequencies of 360 Hz, 720 Hz, 1440 Hz and 2160 Hz, and ripples with peak-to-peak values (pp of rated value) of $4x10^{-2}$, $9x10^{-3}$, $2.4x10^{-3}$ and $7x10^{-4}$. In the table, the diode (or thyristor) currents are assumed to be according to the design requirement. Moreover, Table 3 lists the parameters of the full-wave rectifier circuits in the same manner as Table 2.

The DC ripple of the traction power refers to the output voltage or current from the pulse rectified wave. The ripple expression is a waveform of the peak-to-peak voltage and is represented as dV. A DC traction power voltage of 750 V DC output Vd is shown in Fig. 5. The ripple factor refers to the ratio of the ripple voltage dV and DC voltage Vd. Generally, in a simple computational method, dV is compared to Vd of the pulsating waveform of the peak-to-peak value as a mean value of the DC output voltage. In order to affect the dV, the size is according to the commutating pulse wave number. The ripple factor and ripple factor percentage are given as dV/Vd and dV/Vd × 100%.

Table 2. Summary of Half-Wave Rectifier Circuits and Parameter

Half-Wave	Unit	6 Phases	12 Phase	24 Phase	36 Phases
Frequency	Hz	360	720	1440	2160
Response	10^{-3} Sec	2.77	1.38	0.69	0.46
Ripple	Peak-peak	$4x10^{-2}$	$9x10^{-3}$	$2.4x10^{-3}$	$7x10^{-4}$
Phase Angle	Degree	60^0	30^0	15^0	10^0
No. of Thyristors or Diodes	Piece	6	12	24	36
Current per Diod or Thyristor (Load 1000A)	A	166.6	83.3	41.6	27.7

Table 3. Summary of Full-Wave Rectifier Circuits and Parameter

Full-Wave Bridge	Unit	6 Phases	12 Phase	24 Phase	36 Phases
Frequency	Hz	720	1440	2880	4320
Response	10^{-3} Sec	1.38	0.69	0.34	0.23
Ripple	Peak-peak	$9x10^{-3}$	$2.4x10^{-3}$	$4.3x10^{-4}$	$1.9x10^{-4}$
Phase Angle	Degree	30^0	15^0	7.5^0	5^0
No. of Thyristors or Diodes	Piece	12	24	48	72
Current per Diod or Thyristor (Load 1000A)	A	83.3	41.6	20.8	13.8

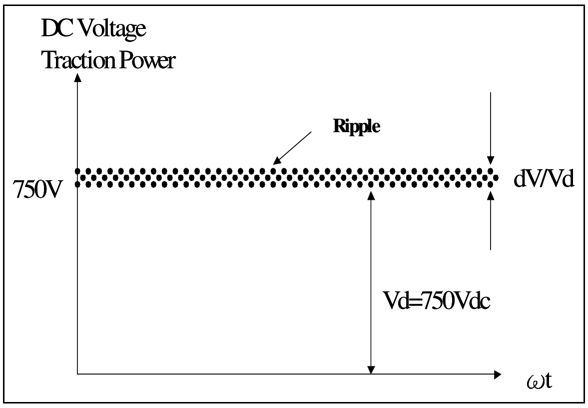


Fig. 5. DC traction power ripples.

This work utilizes the output waveform of the 24 pulse DC traction systems to simulate the characteristics of the ripples by the Matlab program. Each pulse waveform angle of 15^0 for the rectification operation and illustrated as show in Fig. 6. Their corresponding ripple dV is represented with peak to peak value. The dV of the ripple for the simulation waveform is approximately 6.75V, this ideal condition from the 24 pulses of the full wave bridge-type rectifier for output of the DC 750V.

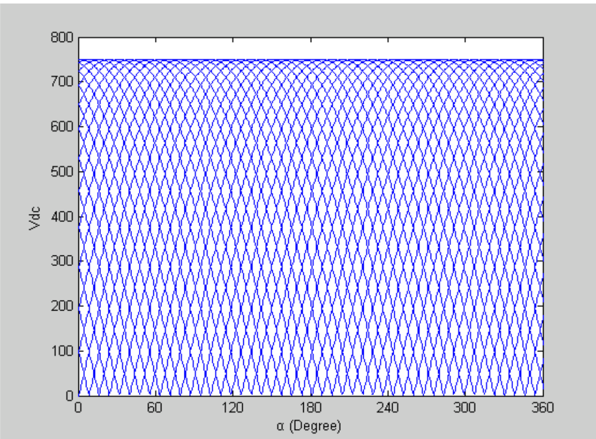


Fig. 6. 24 pulse waveform output.

The waveform dV is revealing the ripple on the DC side. The voltage and current momentarily changes along with the load of dynamic running, its ripple as dV or ΔV as shown in Fig. 7. The dV have including the complex harmonics, its theory correspond to the Fourier's series. Due to the output of ripple harmonics is from operation rectification diode and GTO operation of the inverter in the DC side, after DC voltage and current conversion to train by way of the third rail, and comeback to negative pole of the traction power supply rectifier.

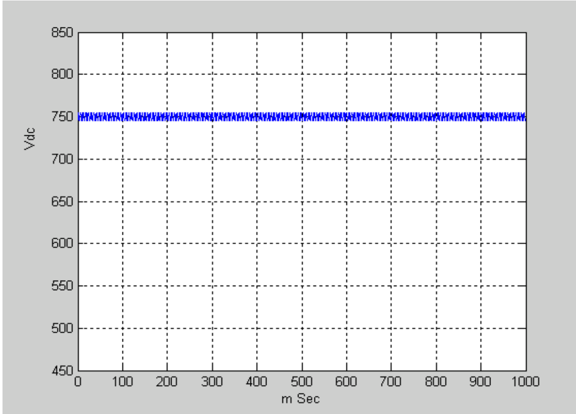


Fig. 7. 24 pulse waveform output ripple.

3 Rectifier Theories

3.1 Traction Power Harmonics

The harmonic frequencies on the dc side of an n-pulse naturally commutated converter are multiples of nf_{ac}, where f_{ac} is the fundamental ac frequency [7]. Consequently, the harmonics of the dc current due to the rectifier are at frequencies:

$$h = pn \pm 1 \qquad n=1,2,3.... \tag{1}$$

where h represents the order of harmonic frequencies, p denotes the pulse number of rectifiers for a 24-pluse inverter, and the dc current harmonic is expressed as a Fourier series, as follows [7-9].

$$I= \frac{4\sqrt{3}}{\Pi} I_d \left[\cos \omega t - \frac{1}{23}\cos 23\omega t + \frac{1}{25}\cos 25\omega t - \frac{1}{47}\cos 47\omega t + ... \right] \tag{2}$$

Where I_d denotes the dc current and I represents the ac phase current. From Eq. (2), the ideal order of harmonics is 1, 23, 25, 47, 49, …. In fact, the harmonic in the traction power is affected by the train loading, distance of the train from the feeding point and other loading from the induction circuit. Therefore, the order and level of these harmonics may be different from those obtained from Eq. (2). The dc harmonic properties of the traction power for MRTS cannot be analyzed only by theoretical predictions.

VVVF inverter of the one group include the 6 pulses wave rectifier and GTO circuits are triggering of angle when α=60°, namely π/6 as show in Eq. (3). Inverter current return to dc traction power supply, the harmonics formula as follows:

$$i(t)=\frac{2\sqrt{3}}{\pi}I_d\left[\cos(\omega t)-\frac{1}{5}\cos(5\omega t)+\frac{1}{7}\cos(7\omega t)-\frac{1}{11}\cos(11\omega t)+\frac{1}{13}\cos(13\omega t)\right.$$
$$\left.-\frac{1}{17}\cos(17\omega t)+\frac{1}{19}\cos(19\omega t)-...\right] \quad (3)$$

The following section outlines general (nonformatting) guidelines to follow. These guidelines are applicable to all authors (except as noted), and include information on the policies and practices relevant to the publication of your manuscript.

3.2 Propulsion Signals

In this simulation, refer to Fourier's series formula and circuit parameter included 24 pulses rectifier, 6 pulses inverter, DC link circuit. DC traction power is uses four groups of 6 pulse waves entire to parallel becomes one group of 24 pulses wave circuit. Triggering of angle when 24 pulse rectifier diode for α=15°, namely π/24, another VVVF inverter one group of 6 pulses wave and GTO circuit as shown in Fig. 8. Triggering of angle when 6 pulse inverter GTO for α=60°, namely π/6. This simulation remove the dynamic propulsion to use PWM, quasi six-step modulation and six-step modulation three stage and neglects load of dynamic running condition of the train speed 0~80KPH to have GTO/IGBT switching time and the inductive load causes Lenz's Law influence of value of delay time and waveform effect.

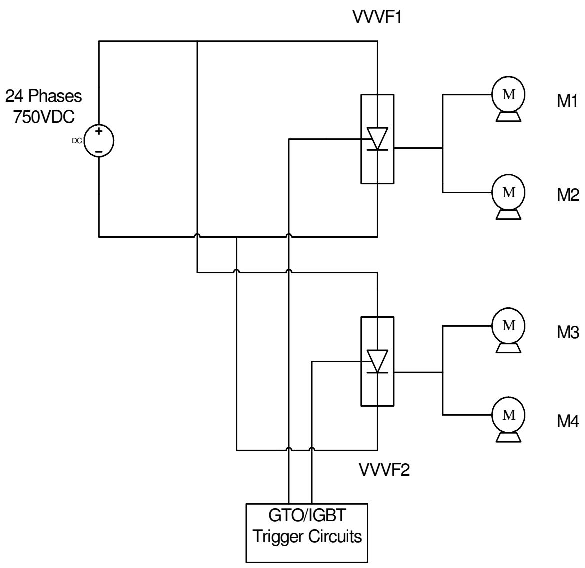


Fig. 8. VVVF inverter system diagram.

Table 4 Gate Cycle Angle Control in the Inverter

VVVF INVERTER	Gate Cycle 1	Gate Cycle 2	Gate Cycle 3	Gate Cycle 4	Gate Cycle 5	Gate Cycle 6
DC—AC Wave Cycle	360^0					
Gate Switch Cycle	180^0			180^0		
Inverter Switching	$0\text{-}60^0$	$60^0\text{-}120^0$	$120^0\text{-}180^0$	$180^0\text{-}240^0$	$240^0\text{-}300^0$	$300^0\text{-}360^0$
GTO Switch Sequence	5-1-6	5-6-4	5-3-4	3-2-4	3-1-2	1-2-6
Output Current Interval	120^0		120^0		120^0	
Output Voltage Interval (Neglect L/C)	120^0		120^0		120^0	

Inverter half-wave rectifier phase parameter list included phase computation with 6, 12, 24 and 36 to corresponding rectification phase angle each as 60^0, 30^0、15^0, 10^0 and the frequency each is 360Hz, 720Hz, 1440Hz and 2160Hz, its ripple corresponds each is $4\text{x}10^{-2}$, $9\text{x}10^{-3}$, $2.4\text{x}10^{-3}$ and $7\text{x}10^{-4}$ peak to peak value (pp of rated value). In the table current parameter of the diode or thyristor assume in the design required, may depend on the design demand revision.

In the table 4 depict the operation gate cycle control angle of 6 pulse GTO/IGBT on the inverter. Concerning the train propulsion system 6 pulse waves of the inverter output to 3 phase AC motor line voltage with v_{ab}、v_{bc}、v_{ca} $2\pi/3 \leqq \omega t \leqq \pi$，phase angle is 30°, Versus line voltage V_{14}, V_{36} and V_{52}.

4 Inverter

Fig. 9 illustrates the circuit of the VVVF inverter composed of (1) six GTO sets (2) low pass filter (inductance L1 and R-C sets), and (3) breaking circuit (R1 and R2). R1, in series with a GTO, is used to receive the breaking energy and dissipate it as heat. The electric braking of motor drives is achieved by causing the motor to act as a generator. The voltage of the input port of the inverter set may be increased and the rising voltage can be dissipated by R2, by opening switch S1.

Each inverter set loads two motors in different phase sequences. The two motors run in opposite directions and should be combined in opposite directions to drive a car. The VVVF inverter has three operation modes. (1) The pulse-width modulation (PWM) mode has a control frequency from 0 to 35 Hz and control speed from 0 to 22KPH. (2) The quasi six-step mode has a control frequency from 35 to 67Hz and control speed from 22 to 42 KPH. (3) The six-step mode has a control frequency above 67Hz and control speed is from 42 to 90KPH as Fig. 10 [1,7-9]. The maximum speed of the motor is 400 RPM at the control frequency of 133Hz. The speed limit under manual operation without automatic train protection is 96 KPH. For the TMRTS, the speed limit is set at 90KPH in the six-step mode, and at 80KPH in the automatic train protection mode.

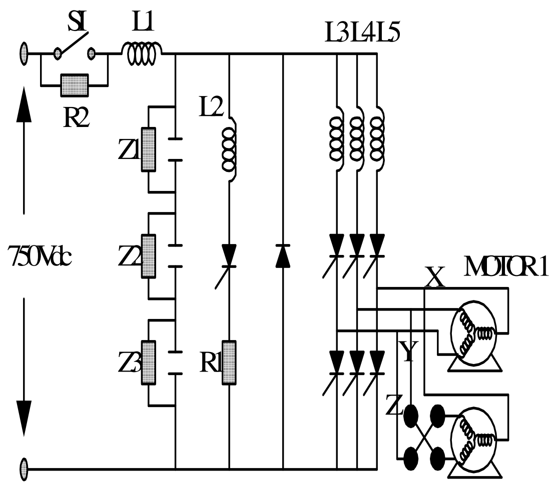


Fig.9. VVVF inverter on train circuits.

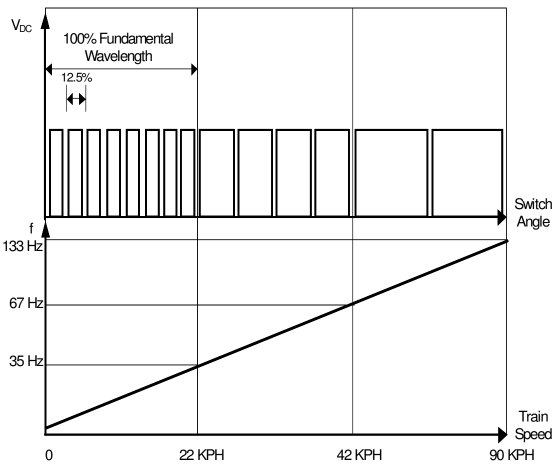


Fig. 10. Inverter speed vs frequency vs angle diagram.

5 Circuits Simulation

Refer to the Fourier's series formula and circuit parameters, this study utilized the 24 pulses rectifier and 6 pulses inverter for the DC link circuit simulation. The DC traction power is composed of the four groups of 6 pulse waves which entire to parallel of the one group with 24 pulses wave circuits. Triggering angle of the 24 pulse rectifier diode individualize as $\alpha=15^o$, namely $\pi/24$. Triggering angle of the 6 pulse inverter GTO is $\alpha=60^o$, namely $\pi/6$. The conditions of the simulation are that (1) neglect of the deviation parameter as a part of the dynamic condition. (2). use the PWM, quasi six-step modulation and six-step modulation, (3) neglects the GTO/IGBT switching time and the inductive load causing of the Lenz's Law influence in the effects on delay time and waveform for the loading of the train under the dynamic running condition as the speed 0~80KPH.

5.1 Inverter Simulation

In this study, the simulation system operate the feature of GTO or IGBT sequence control output of the $i_{Inv}(t)$ of the inverter current feedback to the source of the DC traction power is shown Fig. 11. It is reveal the inverter of GTO serial number 1~6 gates switch branching location and propulsion motor connect of the coils wiring. The output ripple of $\Delta i_{Inv}(t)$ of the inverter current simulate waveform by way of the GTO/IGBT back to the negative terminal of the DC traction power.

For this study, the feature of GTO sequence control output $i_{Inv}(t)$ of inverter feedback to DC source current. It is reveal the inverter of GTO serial number 1~6 gates switch branching location and propulsion motor connect coils wiring.

Inverter output AC waveform and current ripple go back DC traction power supply system that analysis is uses the Matlab program to simulate the Fourier's series on the DC traction power system, under this simulation formula basis ideal condition carries on 24 pulse converter wave and 6 pulse inverter simulations operation function.

The output ripple of $\Delta i_{Inv}(t)$ of the inverter current simulation waveform by way of the GTO/IGBT feedback to DC traction power negative terminal.

The propulsion system use 6 pulses GTO/IGBT VVVF inverter composition, its characteristic harmonics for 6k±1, k=1,2,3···, it is produces the harmonic by series number 5^{th}, 7^{th}, 11^{th}, 13^{th}, 17^{th}, 19^{th}, 23^{rd} and 24^{th} ··· as Fig.12. Current ripple is assuming 750 ampere, this supposition value is consideration easy calculation. In fact the train load current are depend on start, the low speed to high speed operation its current approximately 3,000~4,000 amperes about. Therefore of load current the assume value is take the ideal ripple value computation as Table 2 converter half-wave rectification circuit 6 pulse wave ripple parameter as $4x10^{-2}$, $\Delta i_{Inv}(t)$ current peak to peak value ±15A，inverter output ripple ideal value $\Delta i_{P-P}(t)=\Delta i_{Inv}(t)$, its profile simulation results as show in Fig. 13.

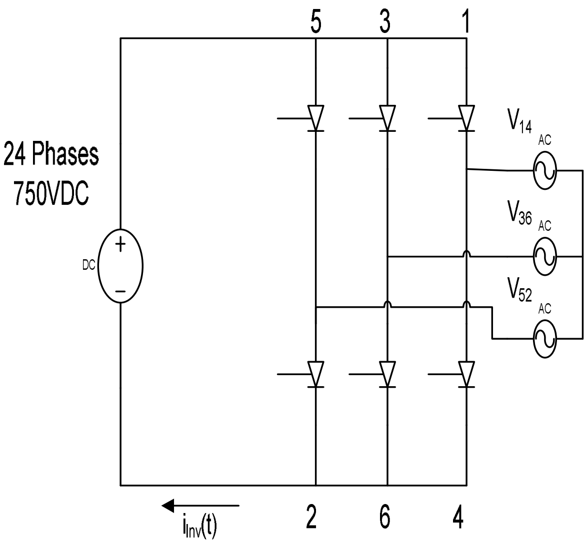


Fig. 11. GTO sequence control diagram.

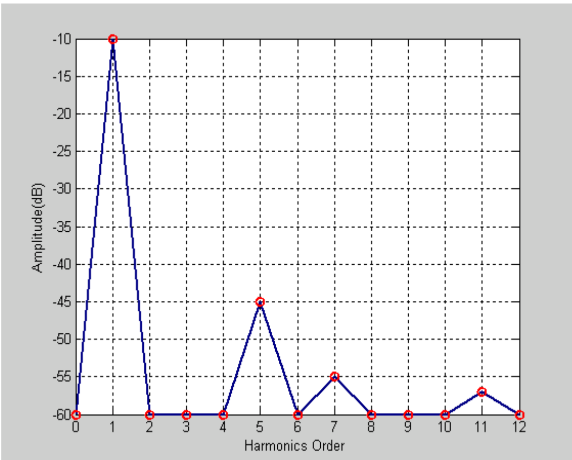


Fig. 12.Inverter harmonic order.

According to theory analysis to combine between 24 pulse wave of commutation and 6 pulse wave of inverter simulation the DC link a. Simulation harmonic of DC traction power system ripple from traction power station AC 22kV/598V provides two group of diode 12 pulse wave rectification commutator 750VDC, after link the DC output connection to GTO/IGBT of 6 pulse by PWM control propulsion motor, the inverter power source return to negative terminal of traction power supply by the wheel to rail track. The load composed by the inverter GTO/IGBT and propulsion motor.

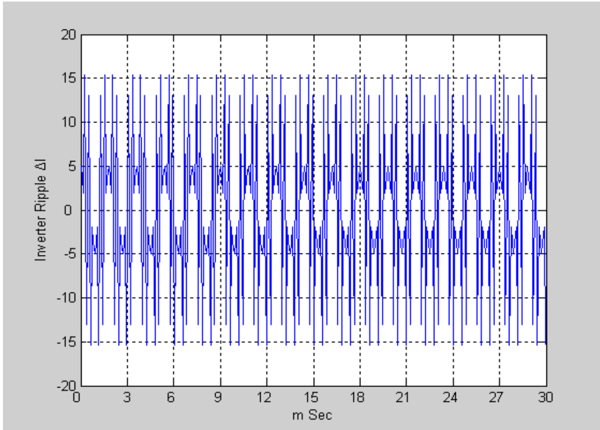


Fig. 13.Inverter circuit output $\Delta i_{Inv}(t)$ simulation waveform.

Fig. 14 simulate the GTO/IGBT control output for vehicle propulsion motor waveform profile. The waveform uses Matlab program simulation train speed 0~40KPH and frequency range is 0~60Hz, output voltage V1 and V4 dc voltage combine as sin wave V1-V4=V14 are the alternating voltage with 3600. Likewise output wave V3-V6=V36 and V5-V2=V52 is also same, has the angle be different only. Therefore these two voltages output waveform same is not draws.

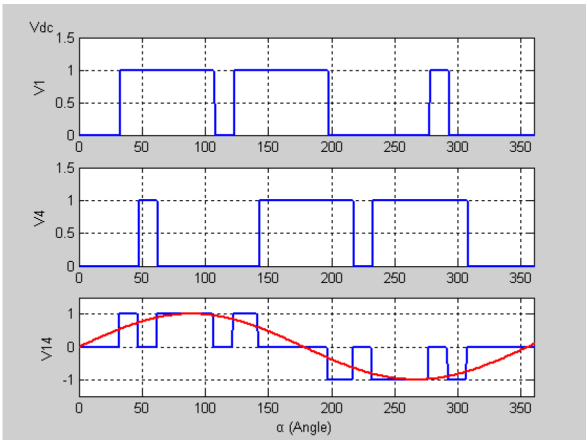


Fig. 14. Inverter AC output V 14.

Fig. 15 simulate the VVVF inverter of GTO/IGBT serial number 1~6 switch branching location and motor induction coils of propulsion system, output 3 phase voltage each is V14, V36 and V52 output waveform to induction motor.

Concerning some parameter definition is difficult in this simulation to give neglects, with another the vehicle itself equipment, cable, GTO and components have produce EMI radiation, disturbance harmonic of ripple, in this simulation give to neglect. Therefore, the parameter make the simulation only by the ideal condition under assume system circuit.

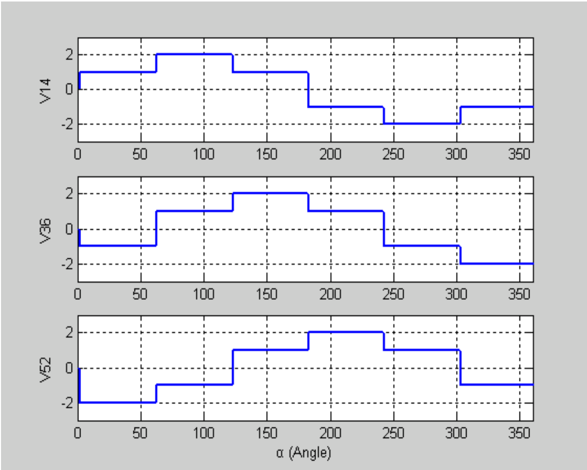


Fig. 15. Inverter AC output 3 phases voltage.

The following assumption are made ripple of output 24 pulse wave rectifier, $i_{Inv}(t)$ is ripple of output 6 pulse inverter that ripple signals produced by GTO switch for output alternation voltage each is 120 degrees. Ripple harmonic simulation are combine DC link loop circuits on the rail track inside content.

Demonstrated estimate of data value based on this investigation, the theoretic and circuit's mathematical analysis and the computer simulation program obtain the result, has the quite ideal. In practical application must consideration to add the variable parameter and regulation control of software program to adjust system control or achieve system requirement.

5.2 Harmonic of Ripple in DC Link Simulation

The theoretical analysis wherein a 24-pulse wave of commutators and 6-pulse wave of the inverter are simulated for the DC link is shown in Fig. 16(a). The simulated ripple harmonic of the DC traction power system are obtained from the traction power station AC 22 kV/598 V that provides two groups of diodes including a combination of two 12-pulse wave rectification commutators 750 V DC, after linking the DC output with 6-pulse GTO/IGBT by the PWM control of the propulsion motor, and the inverter power source returns to the negative terminal of the traction power supply by the wheel of the train to the rail track. The load of the train comprises the inverter GTO/IGBT and propulsion motor.

The harmonic of the ripple obtained from the theoretical analysis is used in the MATLAB program to simulate the Fourier series of the DC traction power system; in this simulation, an ideal condition with a 24-pulse converter wave and 6-pulse inverter is assumed for the Fourier series.

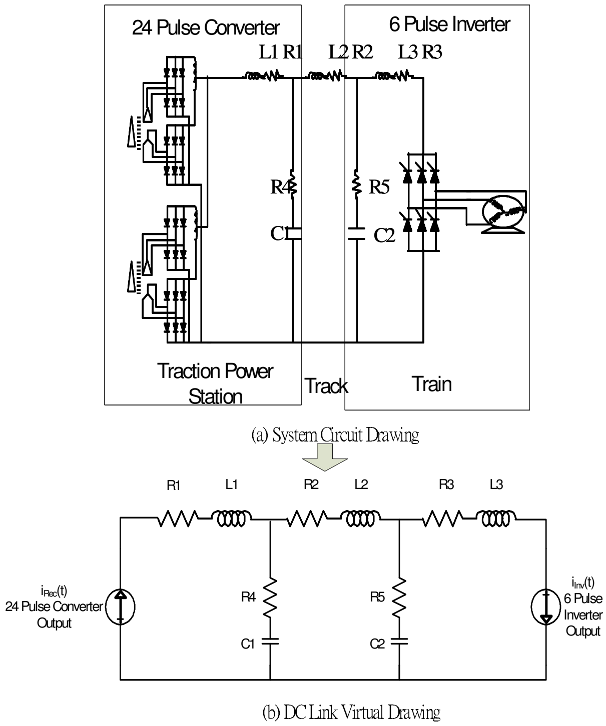
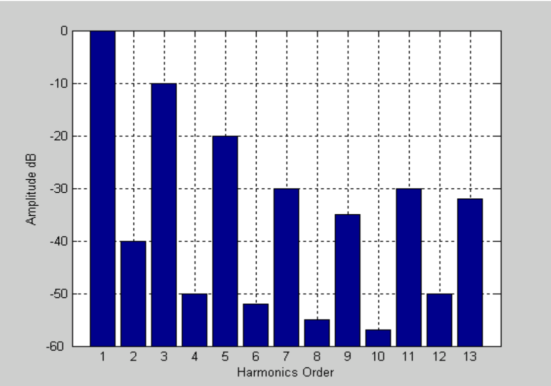


Fig. 16. DC link circuits.

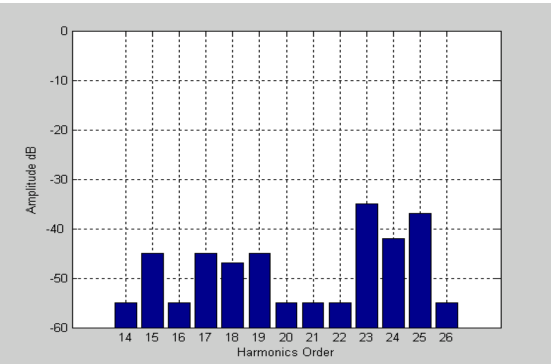
Some parameters may neglected because their definition difficult in this simulation; these include the vehicle itself, and equipment such as the cable, GTO, and other components that produce EMI and radiation that may cause disturbances in the harmonics of the ripple. Therefore, these parameters are only simulated under ideal conditions using the assumed system circuit shown in Fig. 16(b) and parameter shown in Table 4. The following assumptions are made: the DC current ($i_{Rec}(t)$) is a ripple of the output of a 24-pulse wave rectifier, the inverter current ($i_{Inv}(t)$) is the returning ripple of a 6-pulse output, and the signals of the current ripple are produced by GTO switching for alternating the output voltage where the angles are 120° each. The simulated ripple harmonics are combined with the DC link of the loop circuits between $i_{Rec}(t)$ and $i_{Inv}(t)$ on the rail track. The simulation is performed using MATLAB, as shown in Fig.s 17(a) to (f), and the results reveal ripple harmonics No. 1 to 78 for frequencies from 60 Hz to 4680 Hz. The recode of the minimum value is –60dB for the harmonics amplitude; we ignore those less than –60dB, and also ignore harmonic orders after the No. 78.

In the Table 5-6 show results of the simulation data which the first order harmonic of the frequency

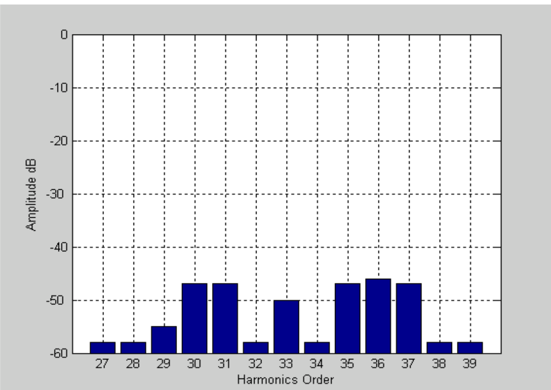
60Hz is 0dB and the others ignore of the under –60dB; for example show harmonics order of No. 1~78. Summarizing of the above data, the amplitude of the odd harmonic is greater than that of the even harmonics. Most harmonics are above –60dB display in the Table. However, the some even order harmonics are greater than –60dB. In particular, some even order harmonics are multiples of the 6th harmonic (360Hz) to reveal in Table.



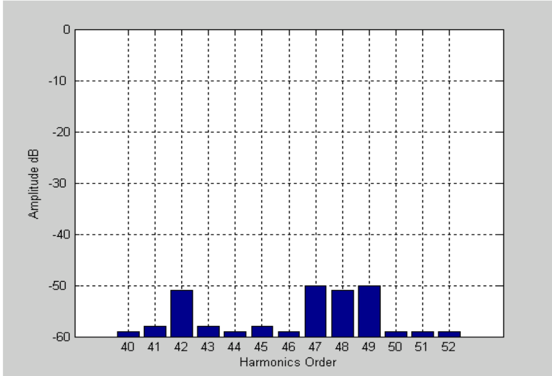
(a).Harmonics No.1~13.



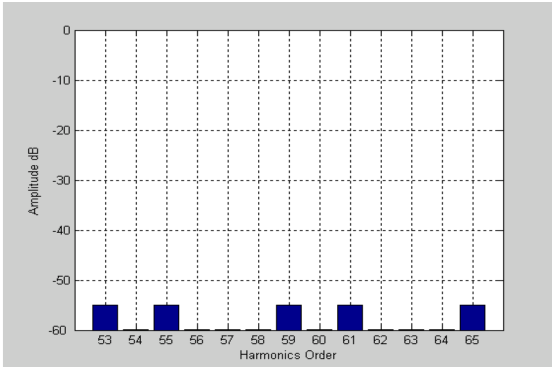
(b).Harmonics No.14~26.



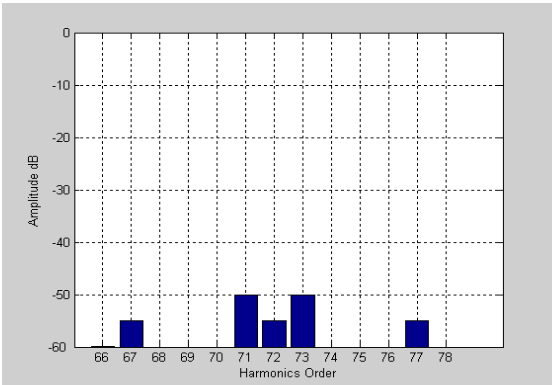
(c).Harmonics No.27~39.



(d).Harmonics No.40~52.



(e).Harmonics No.53~65.



(f).Harmonics No.66~78.

Fig. 17. DC link output harmonic No.1~78.

Table 5. Harmonic Orders with Frequencies List

Orders	Frequency	Amplitude
1th	60 Hz	0dB
2th	120 Hz	-40 dB
3th	180 Hz	-10 dB
4th	240 Hz	-50 dB
5th	300 Hz	-20 dB
6th	360 Hz	-52 dB
7th	420 Hz	-30 dB
8th	480 Hz	-55 dB
9th	540 Hz	-35 dB
10th	600 Hz	-57 dB
11th	660 Hz	-30 dB
12th	720 Hz	-50 dB
13th	780 Hz	-32 dB
14th	840 Hz	-55 dB
15th	900 Hz	-45 dB
16th	960 Hz	-55 dB
17th	920 Hz	-45 dB

18th	980 Hz	-48 dB
19th	1140 Hz	-45 dB
20th	1200 Hz	-56 dB
21th	1260 Hz	-56 dB
22th	1320 Hz	-56 dB
23th	1380 Hz	-35 dB
24th	1440 Hz	-42 dB
25th	1500 Hz	-38 dB
26th	1560 Hz	-56 dB
27th	1620 Hz	-58 dB
28th	1680 Hz	-58 dB
29th	1740 Hz	-55 dB
30th	1800 Hz	-48 dB
31th	1860 Hz	-35 dB
32th	1920 Hz	-57 dB
33th	1980 Hz	-50 dB
34th	2040 Hz	-58 dB
35th	2100 Hz	-48 dB
36th	2160 Hz	-47dB
37th	2220 Hz	-48 dB
38th	2280 Hz	-58 dB
39th	2340 Hz	-58 dB

Table 6. Harmonic Orders with Frequencies List

Orders	Frequency	Amplitude
40th	2400 Hz	-59 dB
41th	2460 Hz	-58 dB
42th	2520 Hz	-51 dB
43th	2580 Hz	-58 dB
44th	2640 Hz	-59 dB
45th	2700 Hz	-58 dB
46th	2760 Hz	-59 dB
47th	2820 Hz	-50 dB
48th	2880 Hz	-52 dB
49th	2940 Hz	-50 dB
50th	3000 Hz	-59 dB
51th	3060 Hz	-59 dB
52th	3120 Hz	-59 dB
53th	3180 Hz	-55 dB
54th	3240 Hz	-60 dB
55th	3300 Hz	-55 dB
56th	3360 Hz	-60 dB
57th	3420 Hz	-60 dB
58th	3480 Hz	-60 dB
59th	3540 Hz	-55 dB
60th	3600 Hz	-60 dB
61th	3660 Hz	-55 dB
62th	3720 Hz	-60 dB
63th	3780 Hz	-60 dB
64th	3840 Hz	-60 dB
65th	3900 Hz	-55 dB
66th	3960 Hz	-60 dB
67th	4020 Hz	-55 dB
68th	4080 Hz	-- dB
69th	4140 Hz	-- dB
70th	4200 Hz	-- dB
71th	4260 Hz	-50 dB
72th	4320 Hz	-55 dB
73th	4380 Hz	-50 dB
74th	4440 Hz	-- dB
75th	4500 Hz	--- dB
76th	4560 Hz	-- dB
77th	4620 Hz	-55 dB
78th	4680 Hz	-- dB

6 Conclusion

In this paper present the analyses results of the signals waveform and ripple with harmonics of the circuits of the traction power systems for the innovation simulation model based on the DC link loop system. This simulation data first reveal the ripple harmonics that the values have provided of the precision analysis for the DC side characteristics between the traction power and vehicle propulsion systems on the TMRTS. In this feature analysis aim at the ripple harmonics data value, compared to the AC harmonics of the IEEE 519 recommendation value, discovers somewhat similarly, therefore in the DC side of the ripple harmonics analysis obtain the precise reference values of waveform. Has the significant meaning to the system stability and reliability analysis.

Besides, in practical application must consideration to add the variable parameter and regulation control of software program to adjust system control and achieve of the system requirement. The results of ripple harmonics and rectifier waveform are based on the ideal condition, that is neglect the dynamic parameter of deviation and miscellaneous by the disturbance and GTO switching from the induce distortion waveform (Lenz's Law) and electromagnetic interference parameter to create the influence value, which can not add in the system, this consideration is development in the future simulation.

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