Concept Kit
Modeling of 3-Phase AC Motor Drive Simulation

For Electric Drive Systems [PSpice Version]

Contents

1.1) Manufacturer Specification

Motenergy, Inc (ME0913)

Motor Electrical Parameters

- Operating Voltage Range.....0 – 72 V_{MAX}
- Rated Continuous Current.....140 Arms
- Peak Stalled Current.....400 Arms
- Voltage Constant.....50 RPM/V
- Phase Resistance (L-L).....0.0125 Ω
- Phase Inductance.....105uH at 120Hz, 110uH at 1kHz
- Maximum Continuous Power Rating……..17KW at 102V_{DC} Battery Voltage

  14.3KW at 84V_{DC} Battery Voltage

  12KW at 72V_{DC} Battery Voltage

Motor Mechanical Parameters

- Rated Speed.....3000 RPM
- Maximum Speed.....5000 RPM
- Rated Torque.....288 Lb-in
- Torque Constant.....1.6 Lb-in/A

1.2) Torque and Back-EMF

- **The Torque are defined by :**

$$\left.\begin{aligned} Tu &= KT \cdot Iu \\ Tv &= KT \cdot Iv \\ Tw &= KT \cdot Iw \end{aligned}\right\} \quad (1)$$

$$Te = Tu + Tv + Tw \quad (2)$$

At 140Arms (Rated Continuous Current)

K_T = 1.6 Lb-in/A

T_{phe} = 1.6 • 140 = 224Lb-in

T_e = 224*3= 672Lb-in

- **The Back-EMF are defined by :**

$$\left.\begin{aligned} Eu &= KE \cdot \omega m \\ Ev &= KE \cdot \omega m \\ Ew &= KE \cdot \omega m \end{aligned}\right\} \quad (3)$$

At 5000 RPM (Maximum Speed)

$E_{phe} \approx V_{BAT}$ (In an ideal motor, R and L are zero)

E_{phe} = 102V

$K_E = E_{phe} / \omega_m$ = 102 / 5000

$K_E \approx$ 0.02V/RPM

※ **phe** : u, v, w

V_{phe} : Phase voltage applied from inverter to motor

V_{AC} : Operating voltage range (Maximum voltage)

V_{BAT} : DC Voltage applied from battery

I_{phe} : Phase current

T_{phe} : Electric torque produced by u, v, w phase

T_e : Electric torque produced by motor

E_{phe} : Phase Back-EMF

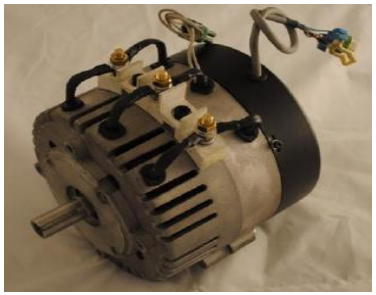
KE : Back-EMF constant

KT : Torque constant

ω_m : Angular speed of rotor

※1 Pound Inch equals 0.11 Nm

1.3) Simplified 3-Phase AC Motor Model



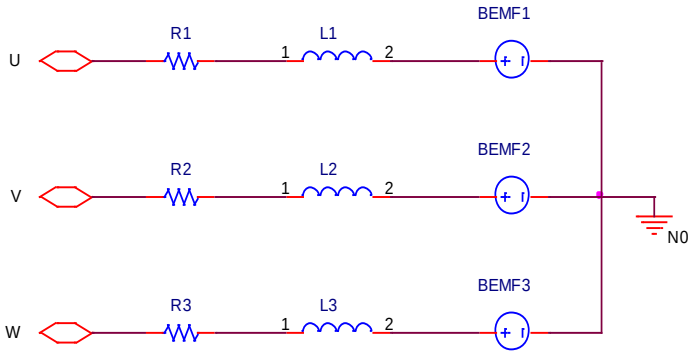


Fig. 1 Scheme of the 3-Phase Model

Frequency Response

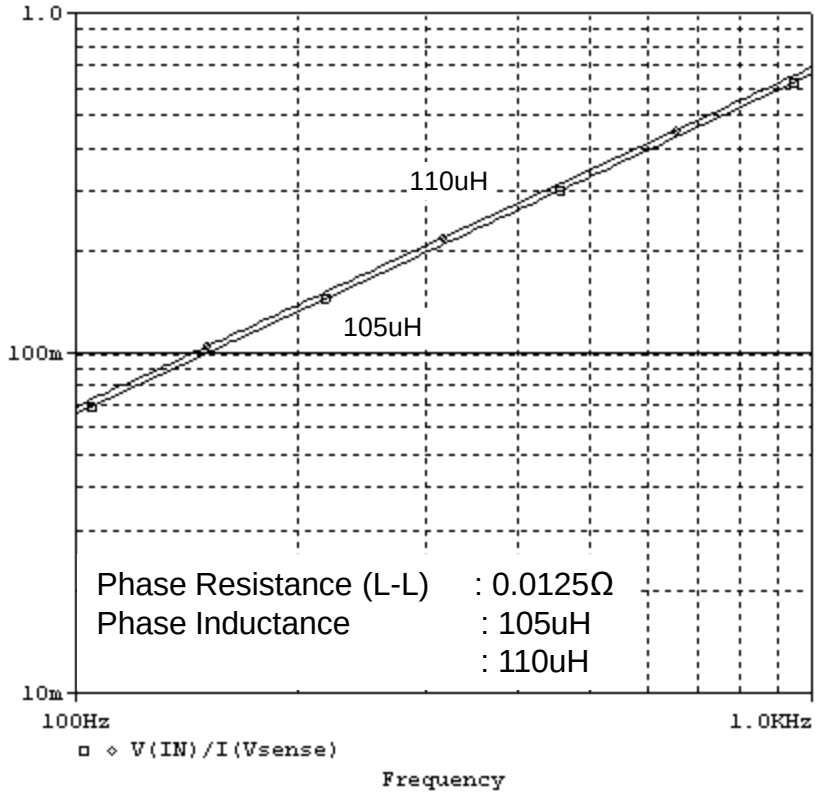


Fig.2 Phase-to-Ground

1.4) The 3-Phase AC Motor Equivalent Circuit

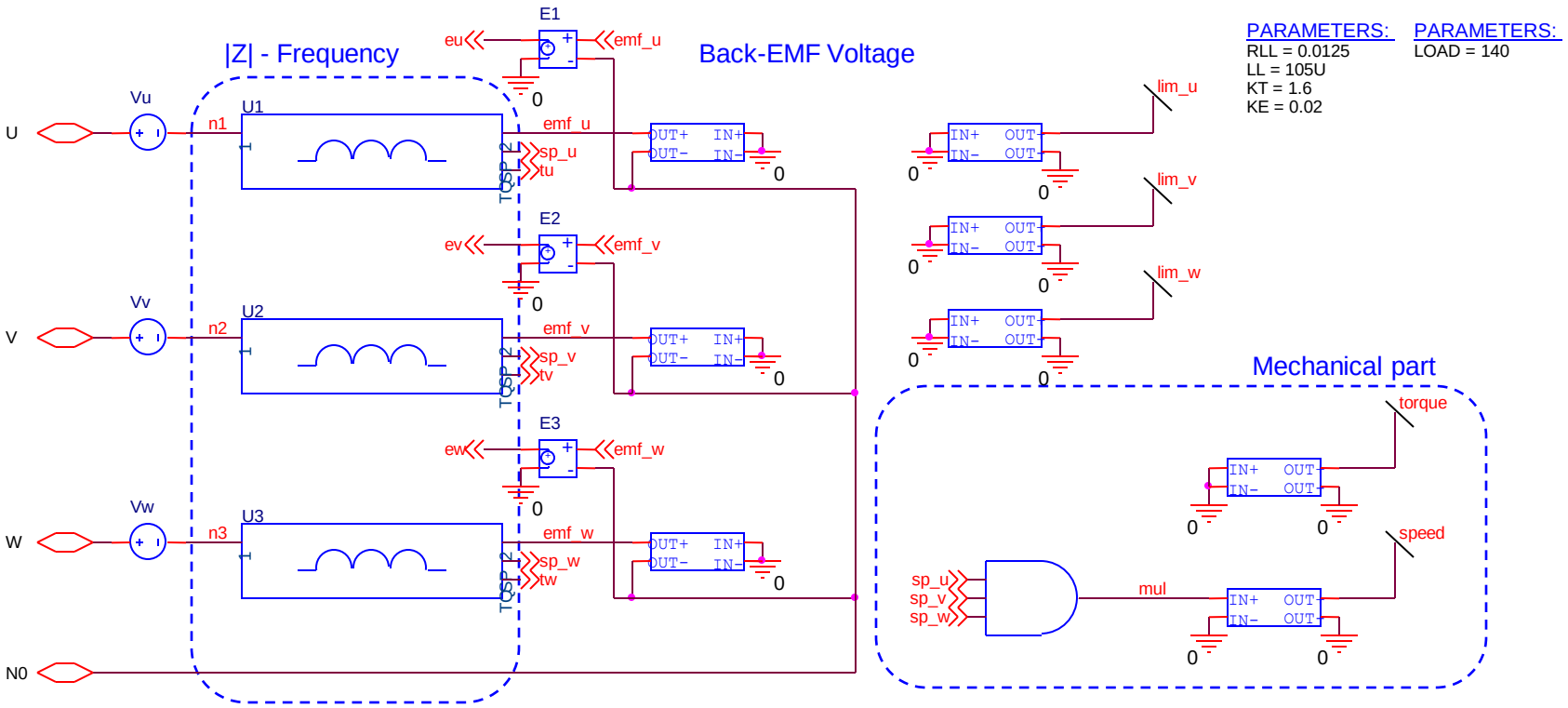


Fig. 3 Three-Phase AC Motor Equivalent Circuit

- This figure shows the equivalent circuit of AC motor model that includes the |Z|-frequency part ,Back-EMF voltage part ,and Mechanical part.
- The Back-EMF voltage is the voltage generated across the motor's terminals as the windings move through the motor's magnetic field.

1.5) Parameters Settings

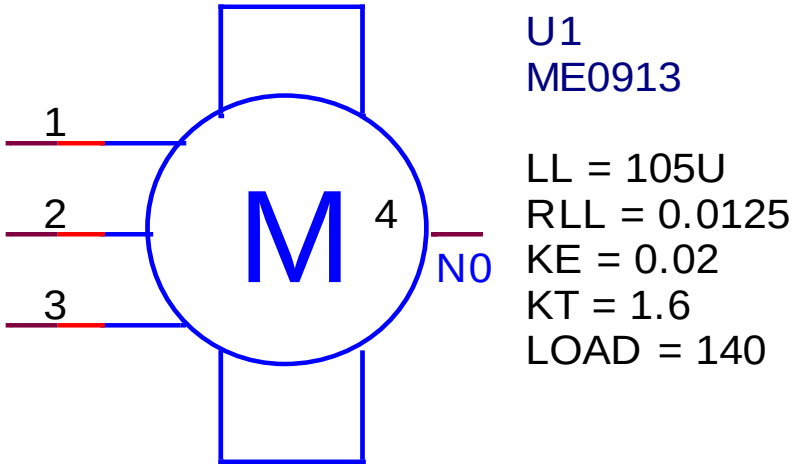


Fig. 4 Symbol of 3-Phase Induction Motor

Model Parameters:

LOAD : Load current each phase of motor [Arms]
- e.g. LL = 125Arms, 140Arms, or 400Arms

LL : Phase inductance [H]
- e.g. LL = 10mH, 100mH, or 1H

RLL : Phase resistance (Phase-to-phase) [Ω]
- e.g. RLL = 10mΩ, 100mΩ, or 1Ω

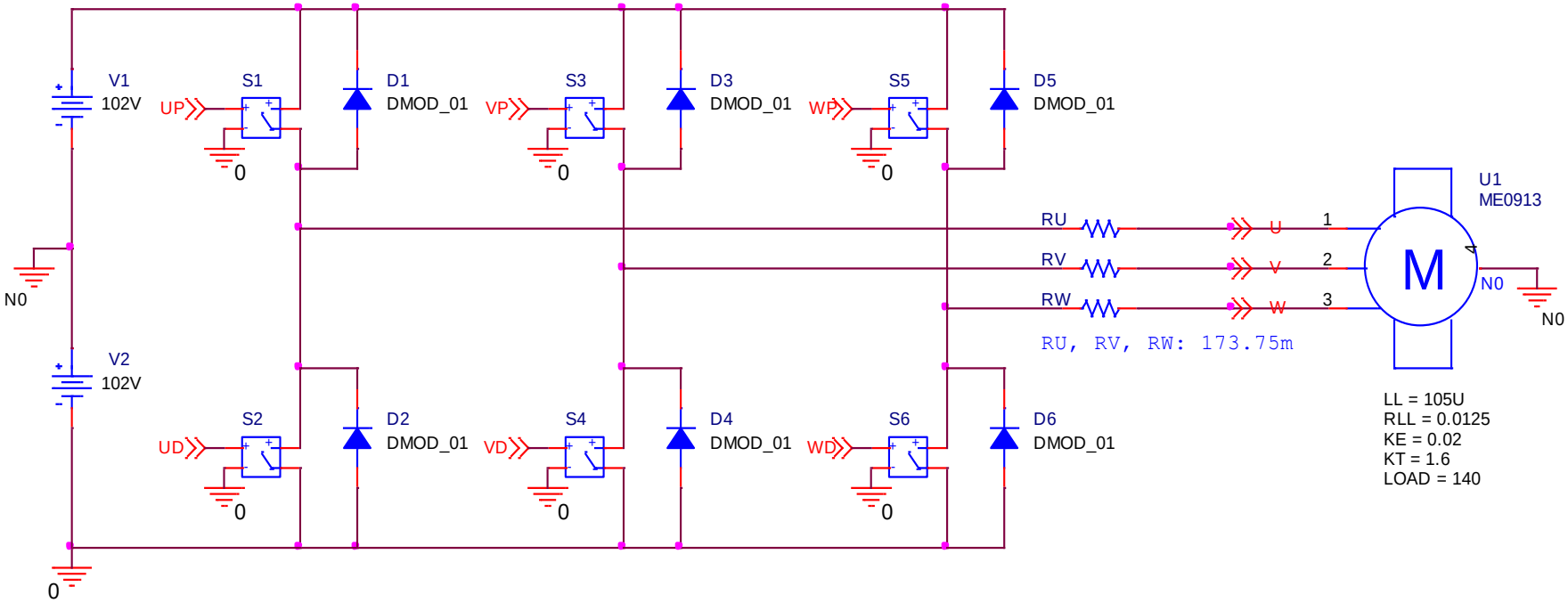
KE : Back-EMF constant [V/RPM]
- e.g. KE= 0.01, 0.05, or 0.1

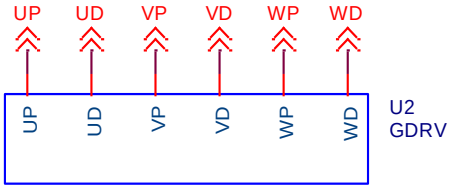
KT : Torque constant [Lb-in/A]
- e.g. KT= 0.1, 0.5, or 1

※1 Pound Inch equals 0.11 Nm

- From the 3-Phase Induction Motor specification, the model is characterized by setting parameters LL, RLL, KE, KT and LOAD.

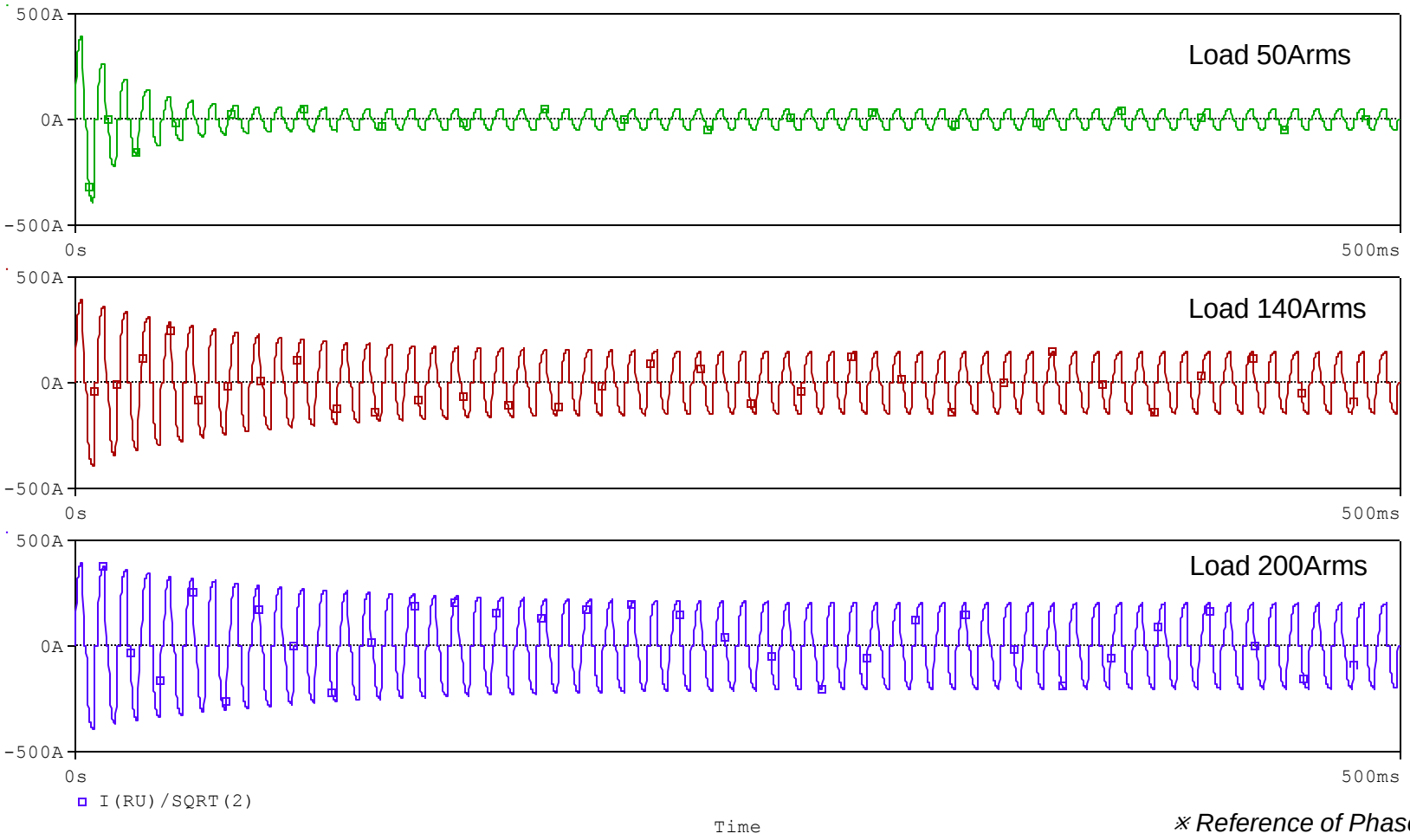
2) Simulation Circuit of 3-Phase AC Motor Model





- Fig.5 Analysis of motor operation powered by alternating voltage variation involves using the model of three-phase induction motor.

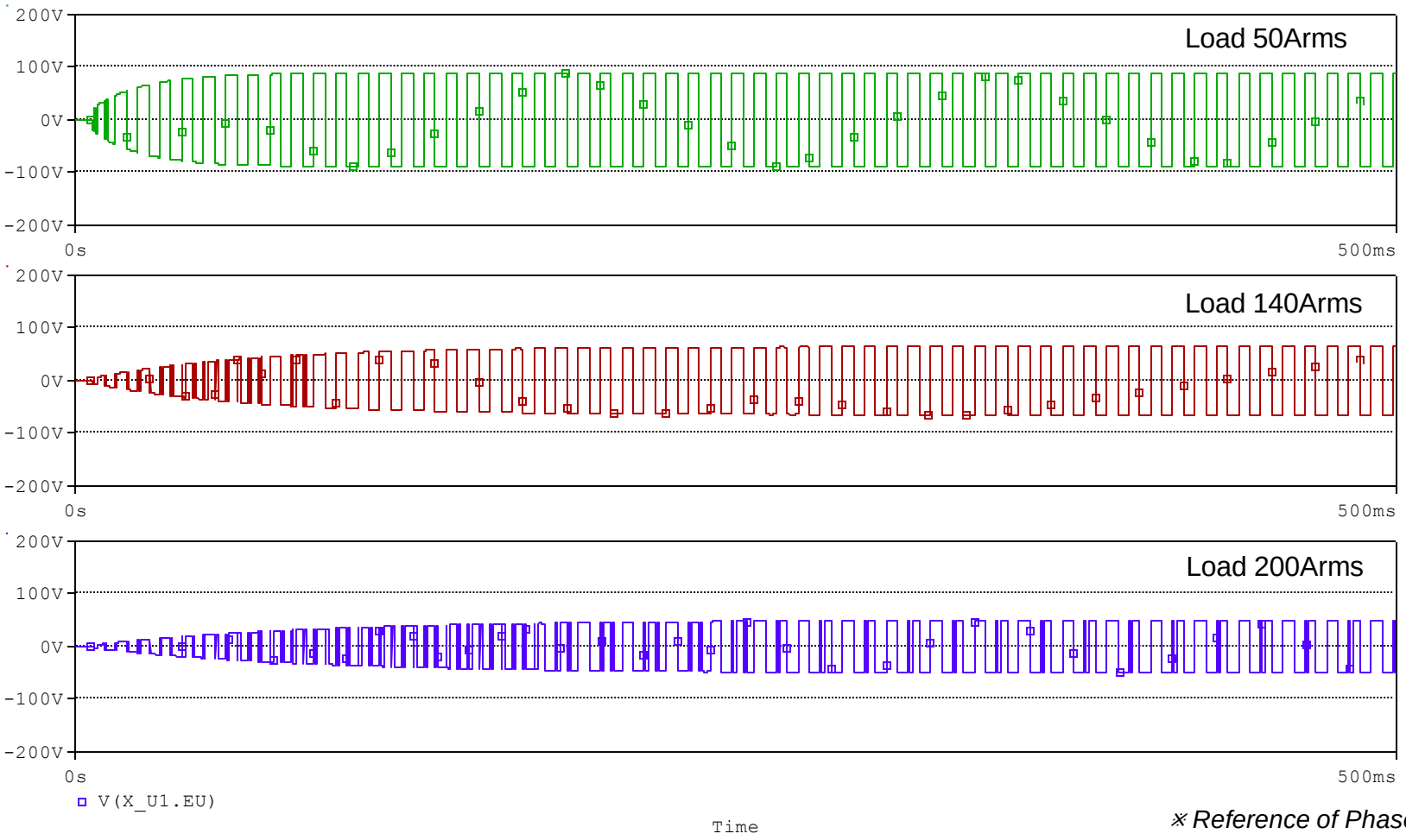
2.1) Phase Current Characteristics Under Load Variation - Simulation Results



※ *Reference of Phase U*

Fig. 6 Current Characteristics under load Condition

2.2) Back-EMF Characteristics Under Load Condition - Simulation Results



※ *Reference of Phase U*

Fig. 7 Back-EMF Characteristics under load Condition

2.3) Speed and Torque Characteristics At 140Arms - Simulation Results

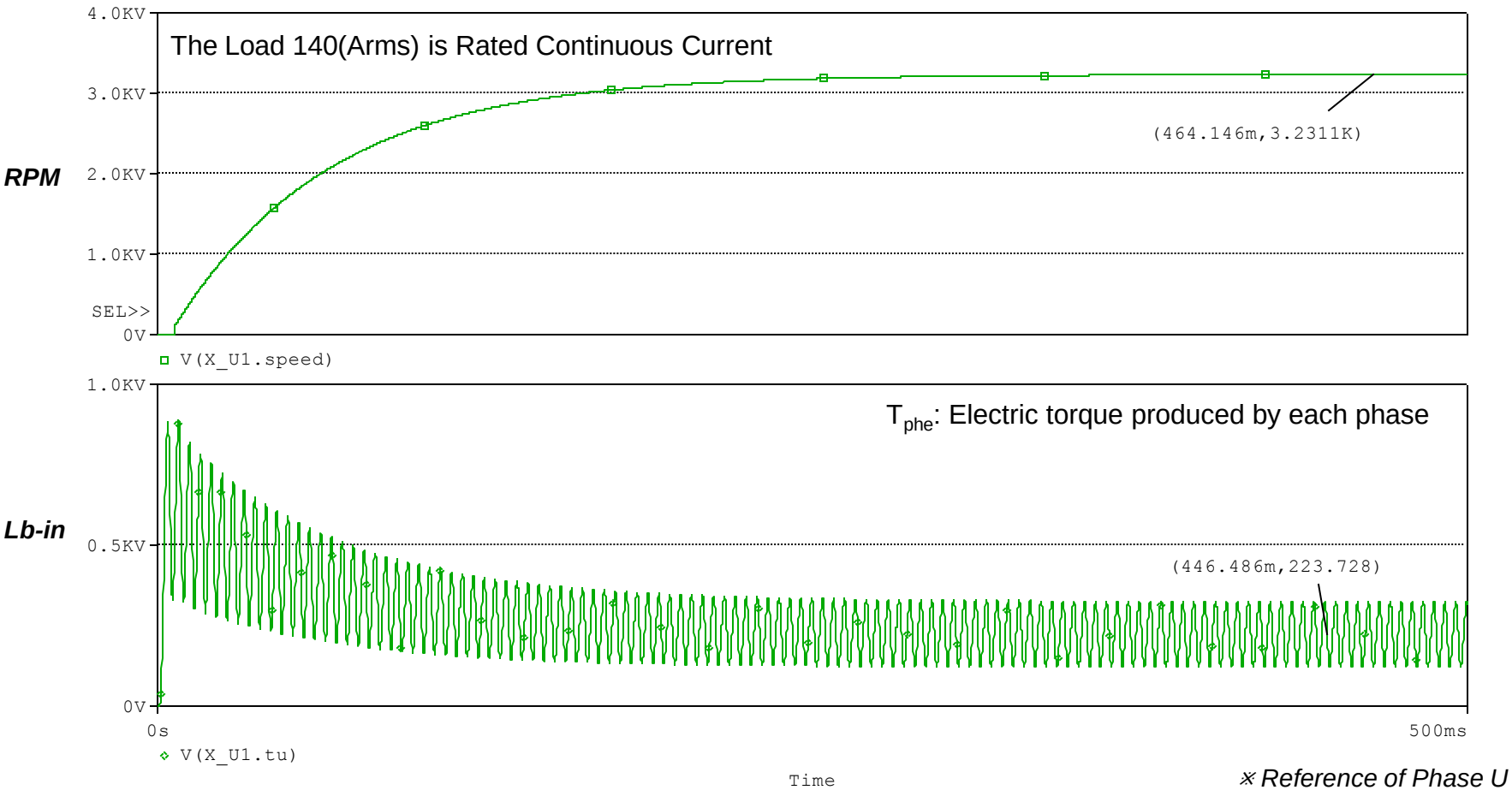
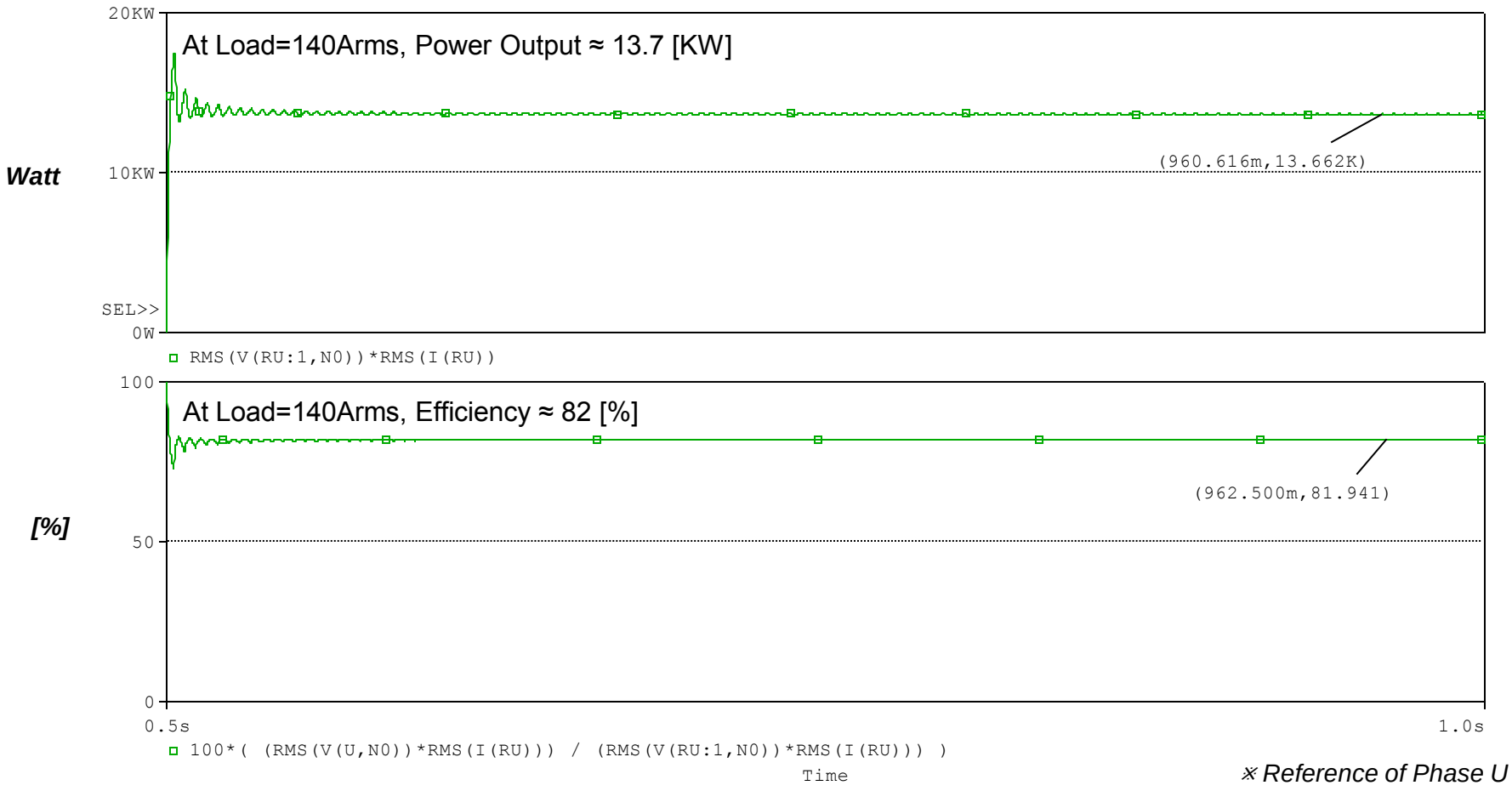


Fig. 8 Speed and Torque Characteristics at Load=140Arms

2.4) Power Output and Efficiency Characteristics At 140Arms - Simulation Results



※ *Reference of Phase U*

Fig. 9 Power Output and Efficiency Characteristics at Load=140Arms