APPENDIX A

TSE Program Code Structure

This appendix shows TSE program code structure which written in MATLAB and corresponded with test system in figure 3.2. The TSE algorithm consists of 5 parts follow list below.

1) TSE part: Main program for determine the component parameter, construction of network topology, calculation of state variable, modal to phase transformation and performance evaluation.
2) Build H part: Construction of [*H*] and [*Z*] matrix according with measurement data.
3) Modal Trans part: Modal transformation for phase to modal domain.
4) Add Tline part: Construction of Bergeron transmission line parameter to [*H*] matrix.
5) Add hline part: Setting a measurement data to correct position in [*H*] matrix.

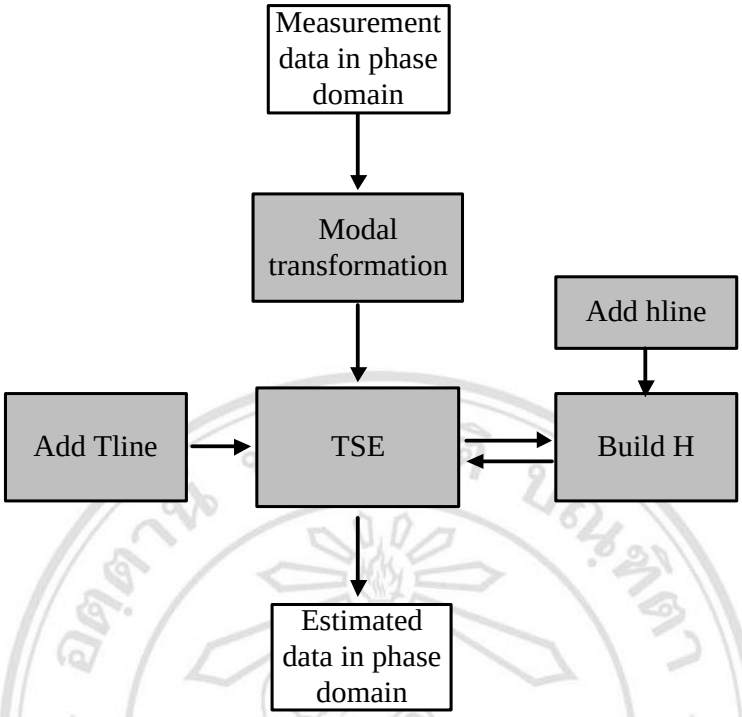

Figure A.1 TSE program code structure.

APPENDIX B

Estimation Results in Different Sag Voltage

The estimation results in chapter 3 show only 80% sag case. This appendix shows estimation results in different sag level and five cases are used for consideration (include three subcases of noise); TSE algorithm, TSE algorithm with 1%, 2%, 3% noise and TSE algorithm with nonlinear equipment (saturated transformer). Table B.1 is the list of estimation result's figures in different sag voltage for each case.

Table B.1 List of figures of estimation results in different sag voltage.

Figure no.	Case	Type of disturbance	Location
Figure B.1	TSE	Three phase	bus no. 5
Figure B.2			bus no. 7
Figure B.3		Single phase	bus no. 5
Figure B.4			bus no. 7
Figure B.5	TSE with 1% noise	Three phase	bus no. 5
Figure B.6			bus no. 7
Figure B.7		Single phase	bus no. 5
Figure B.8			bus no. 7
Figure B.9	TSE with 2% noise	Three phase	bus no. 5
Figure B.10			bus no. 7
Figure B.11		Single phase	bus no. 5
Figure B.12			bus no. 7
Figure B.13	TSE with 3% noise	Three phase	bus no. 5
Figure B.14			bus no. 7
Figure B.15		Single phase	bus no. 5
Figure B.16			bus no. 7
Figure B.17	TSE with saturated transformer	Three phase	bus no. 5
Figure B.18			bus no. 7
Figure B.19		Single phase	bus no. 5
Figure B.20			bus no. 7

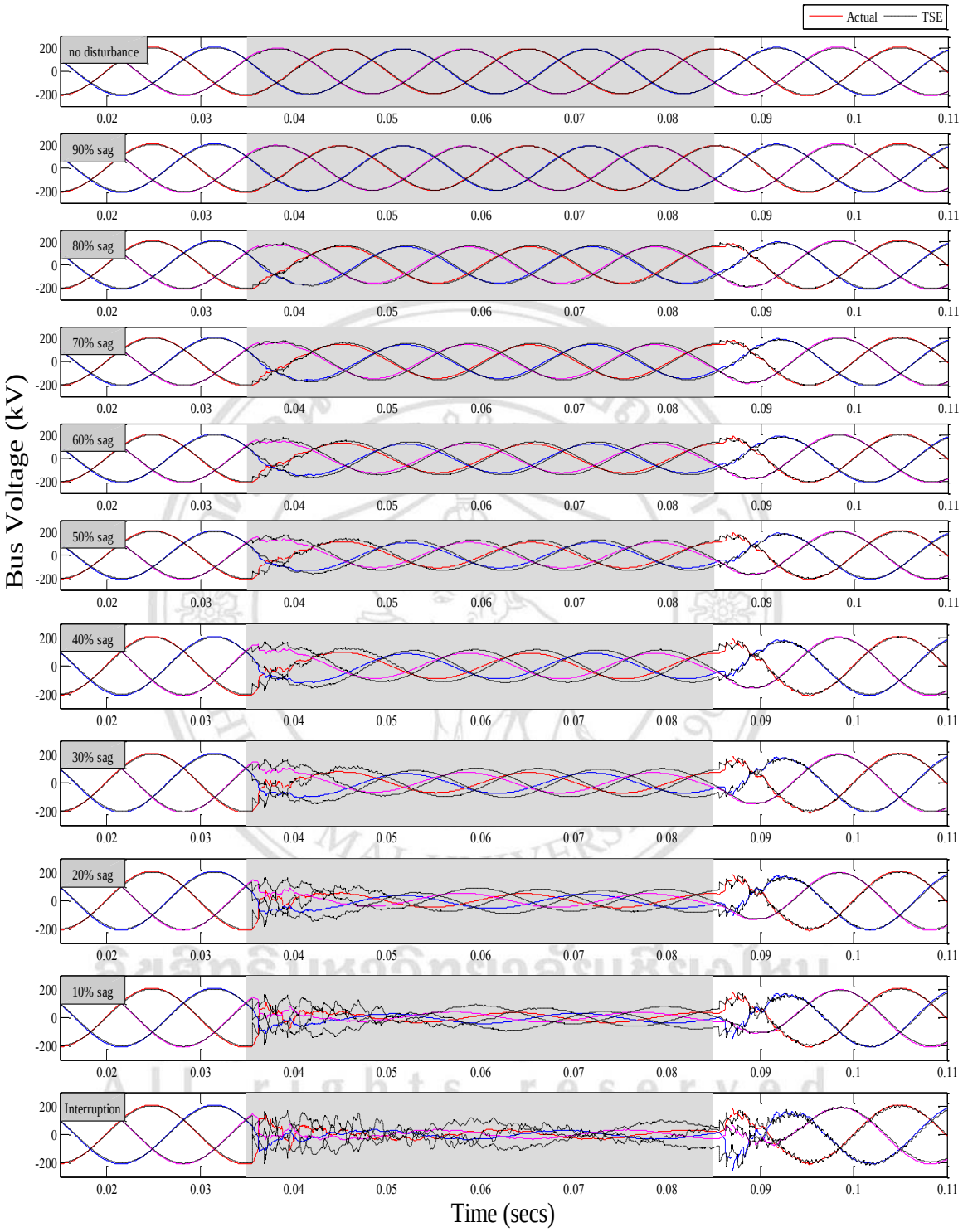

Figure B.1 Voltage at bus no.5 (three-phase disturbance, different sag)

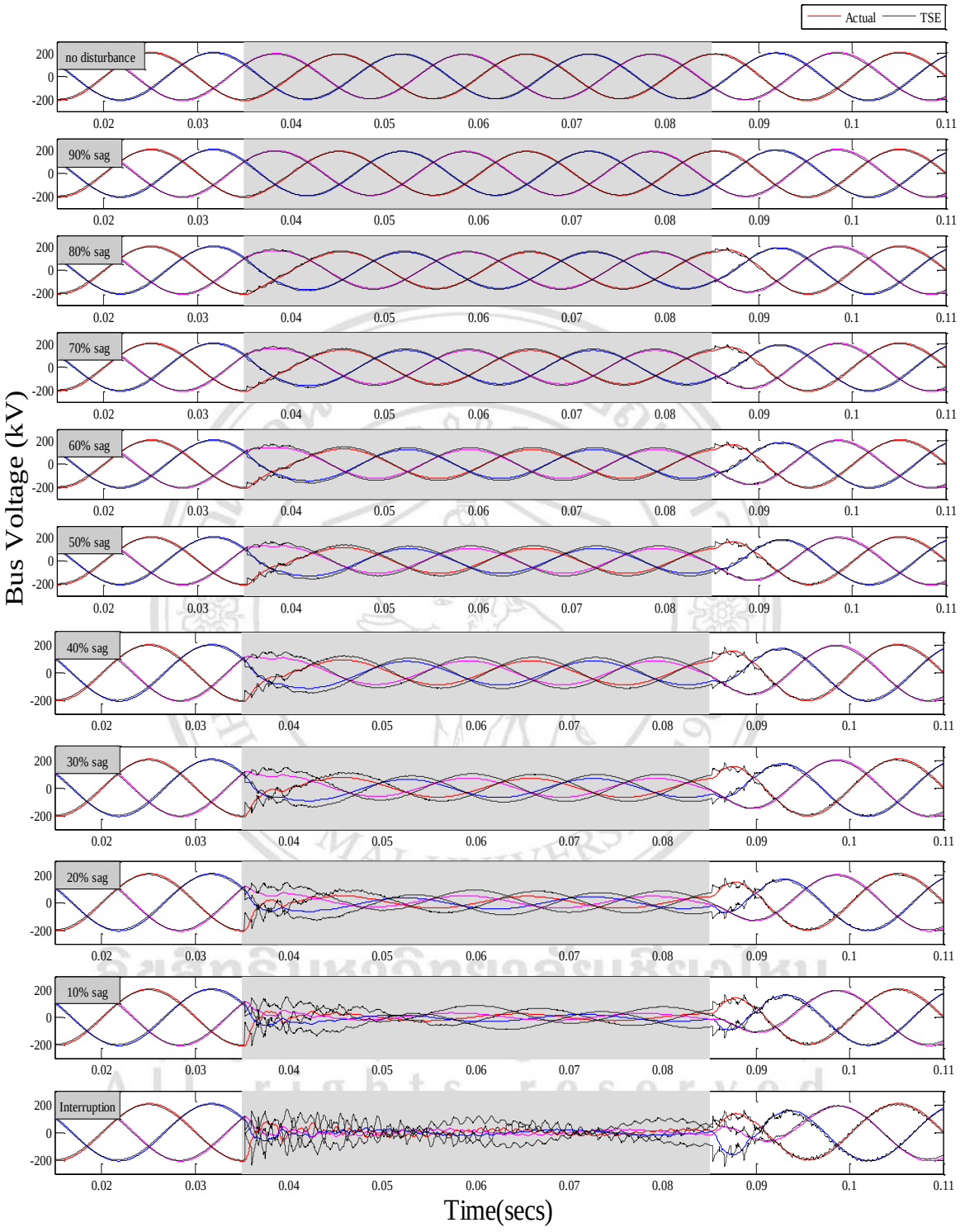

Figure B.2 Voltage at bus no.7 (three-phase disturbance, different sag).

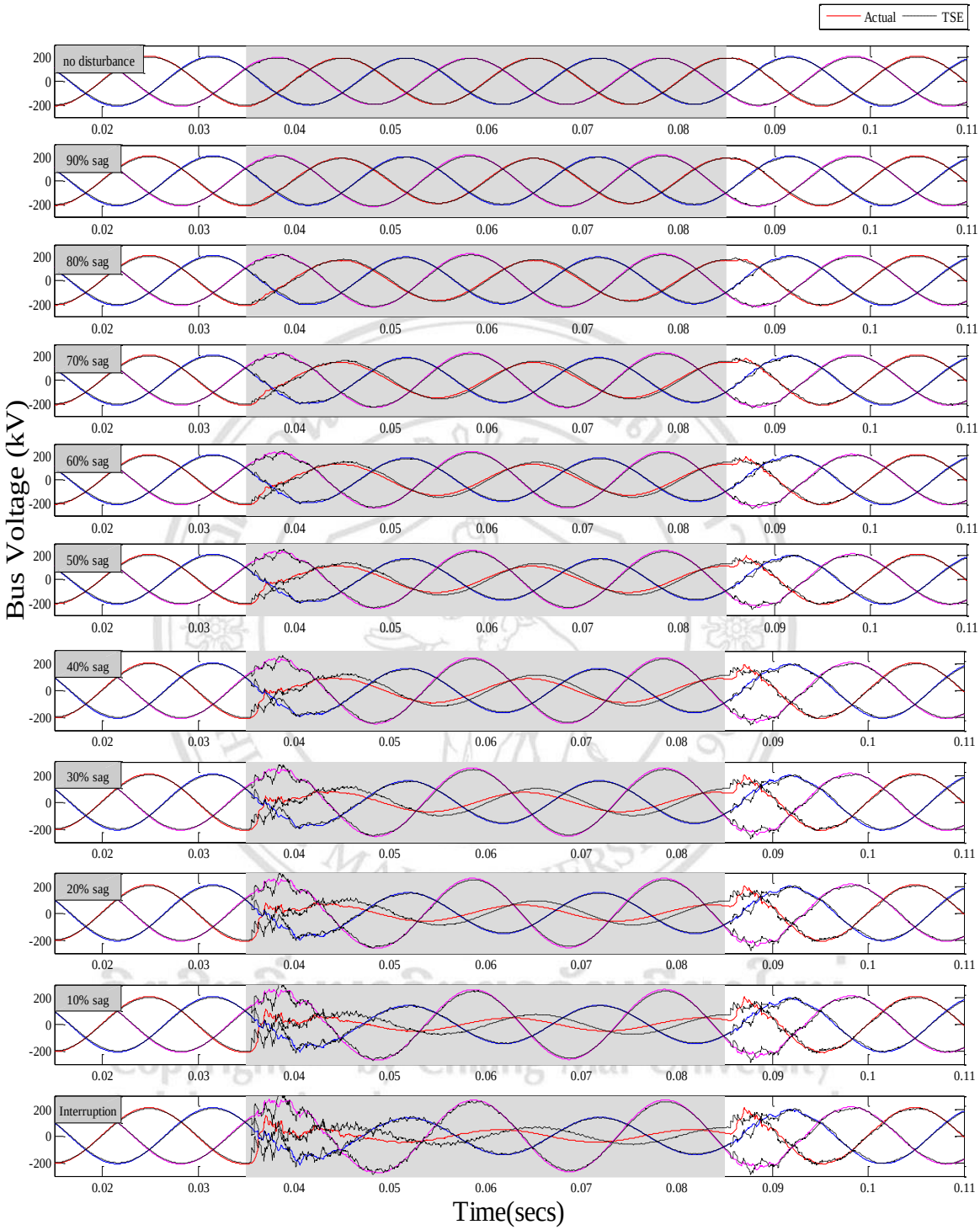

Figure B.3 Voltage at bus no.5 (single-phase disturbance, different sag).

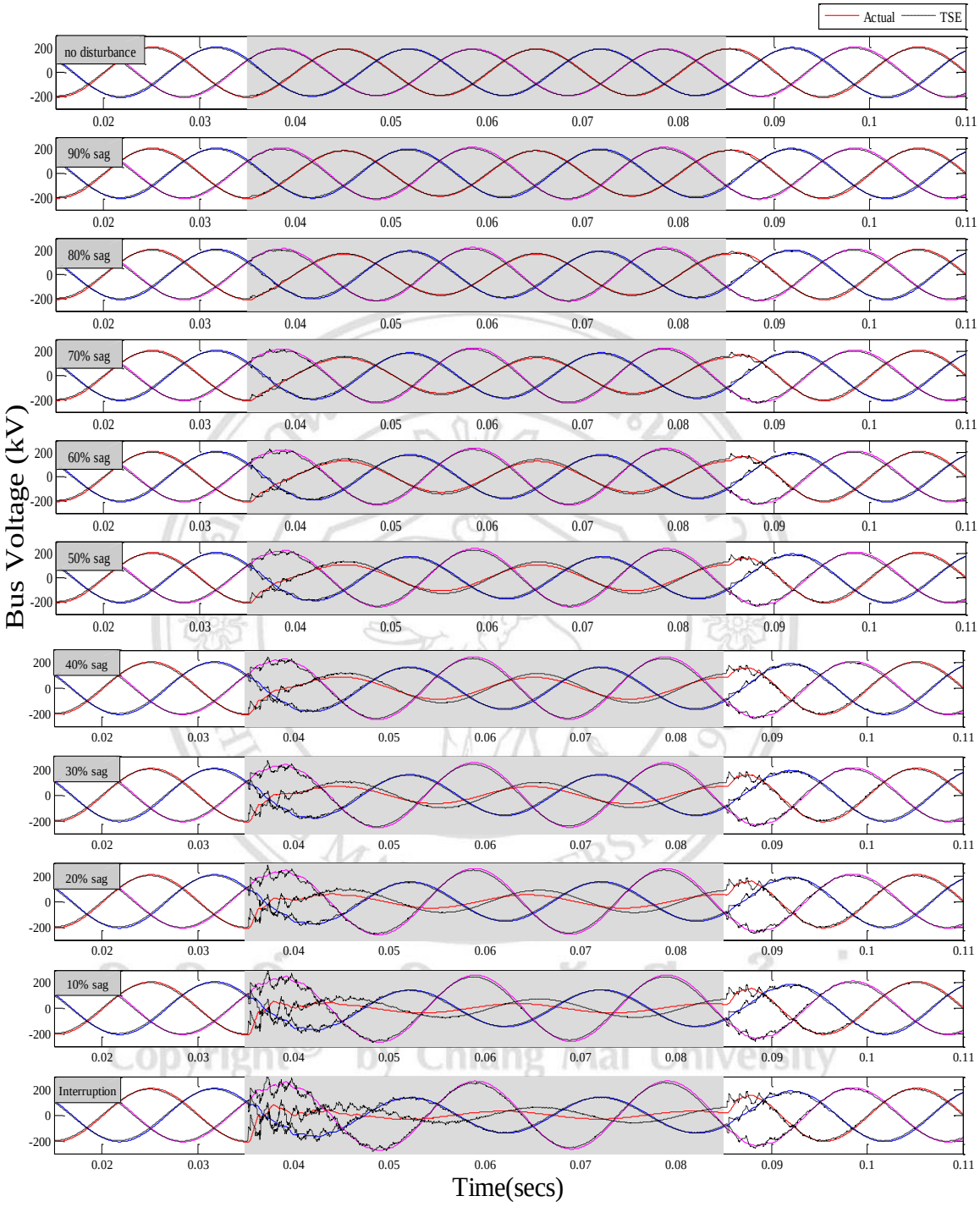

Figure B.4 Voltage at bus no.7 (single-phase disturbance, different sag).

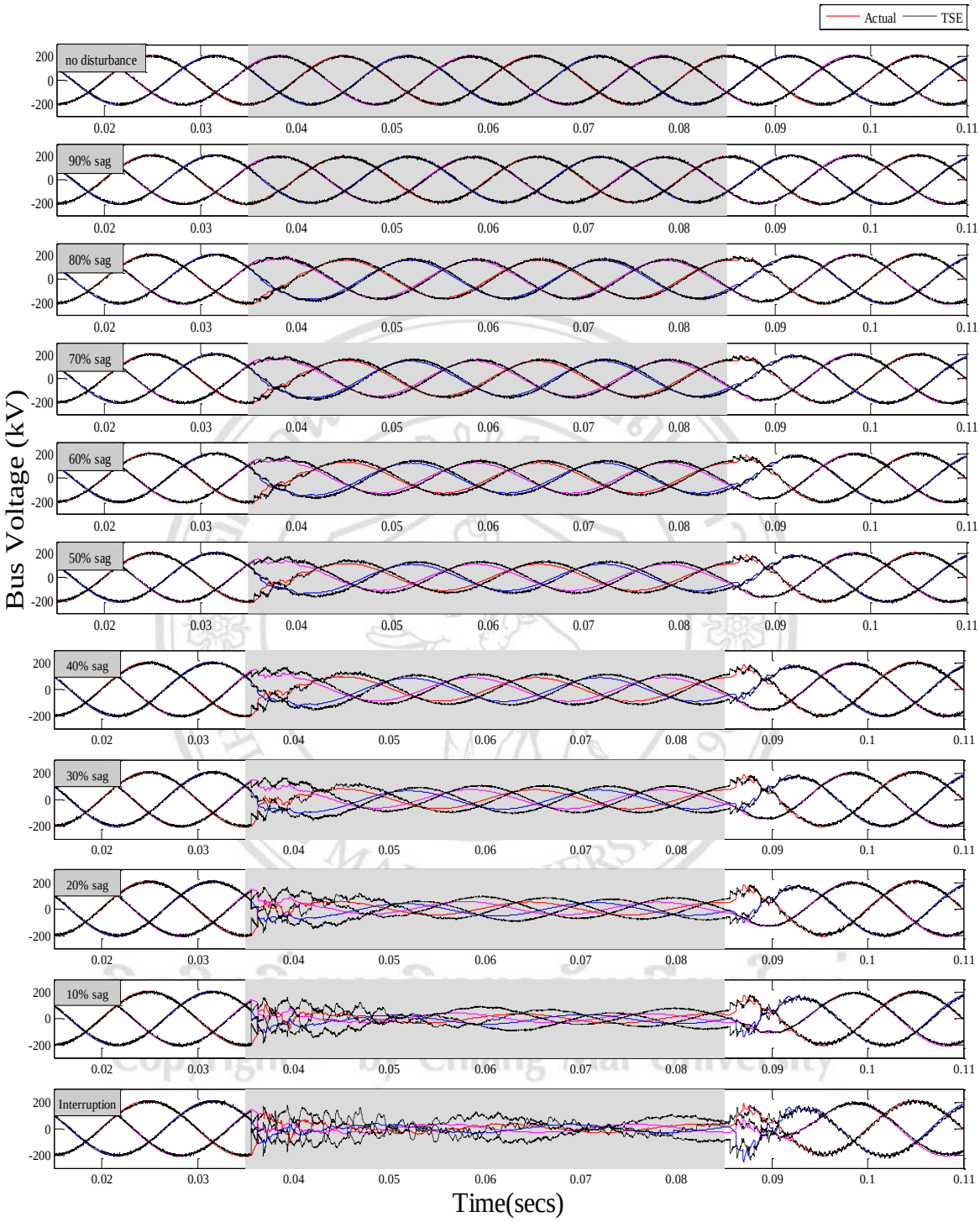

Figure B.5 Voltage at bus no.5 (three-phase disturbance, different sag with a 1% measurement noise).

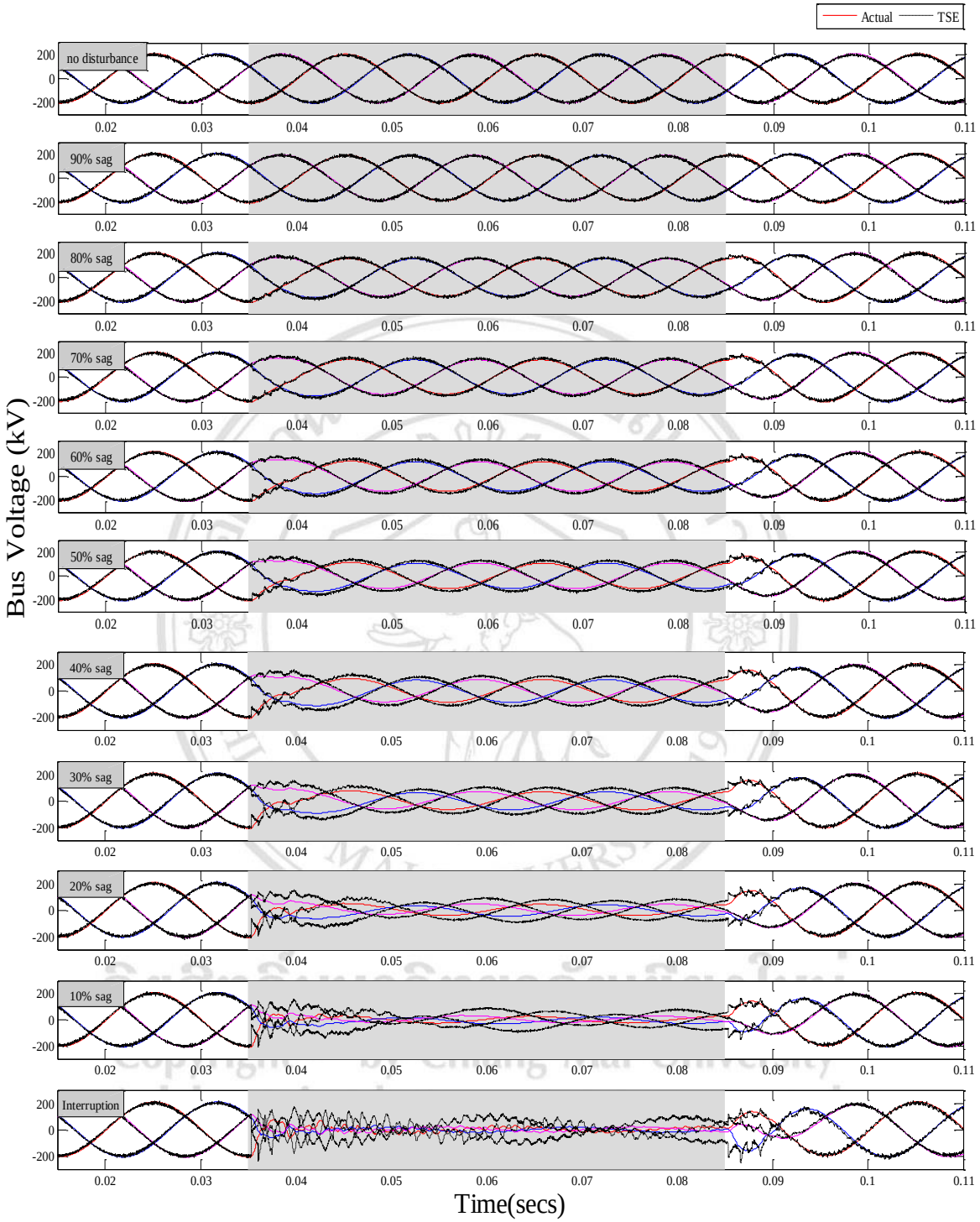

Figure B.6 Voltage at bus no.7 (three-phase disturbance, different sag with a 1% measurement noise).

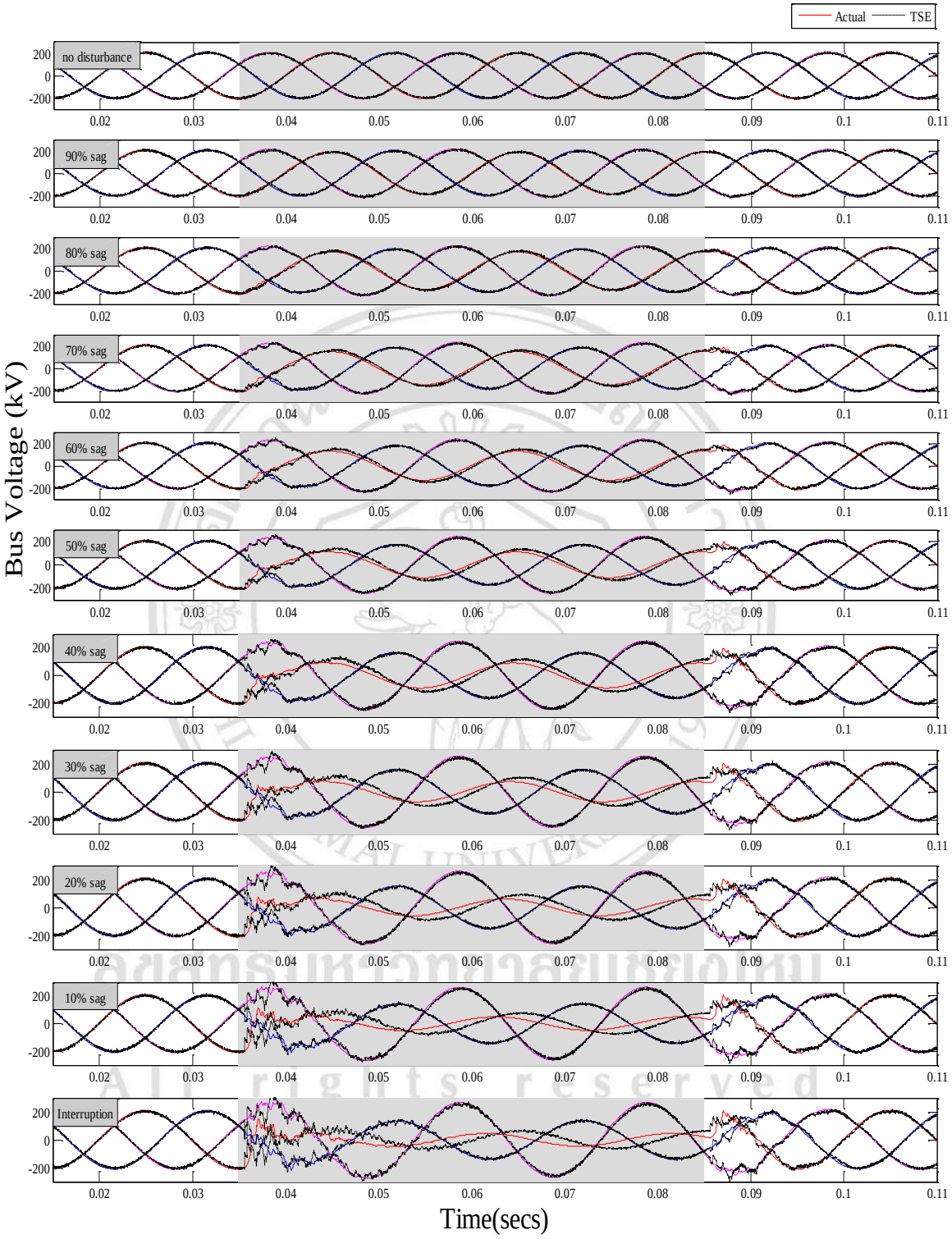

Figure B.7 Voltage at bus no.5 (single-phase disturbance, different sag with a 1% measurement noise).

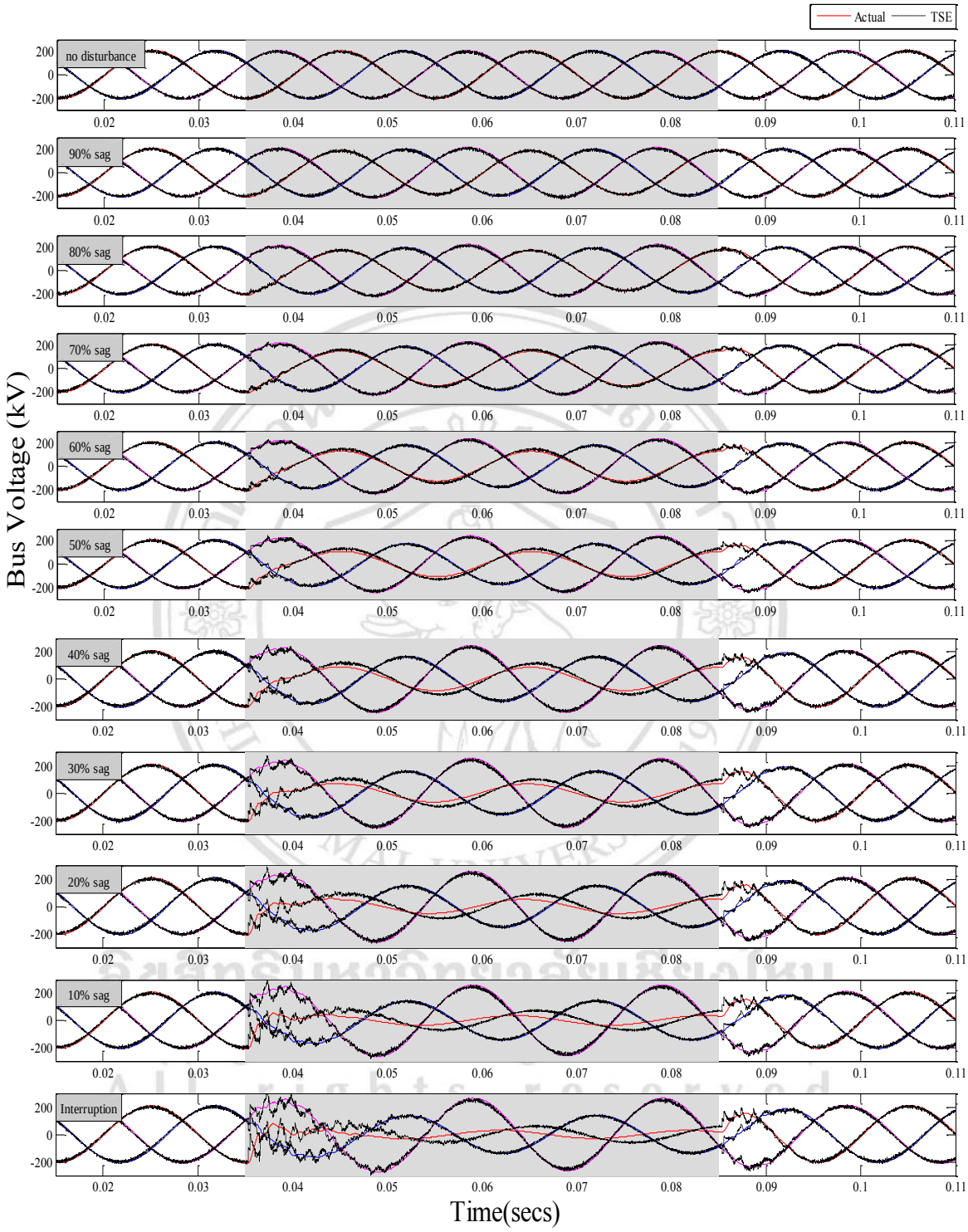

Figure B.8 Voltage at bus no.7 (single-phase disturbance, different sag with a 1% measurement noise).

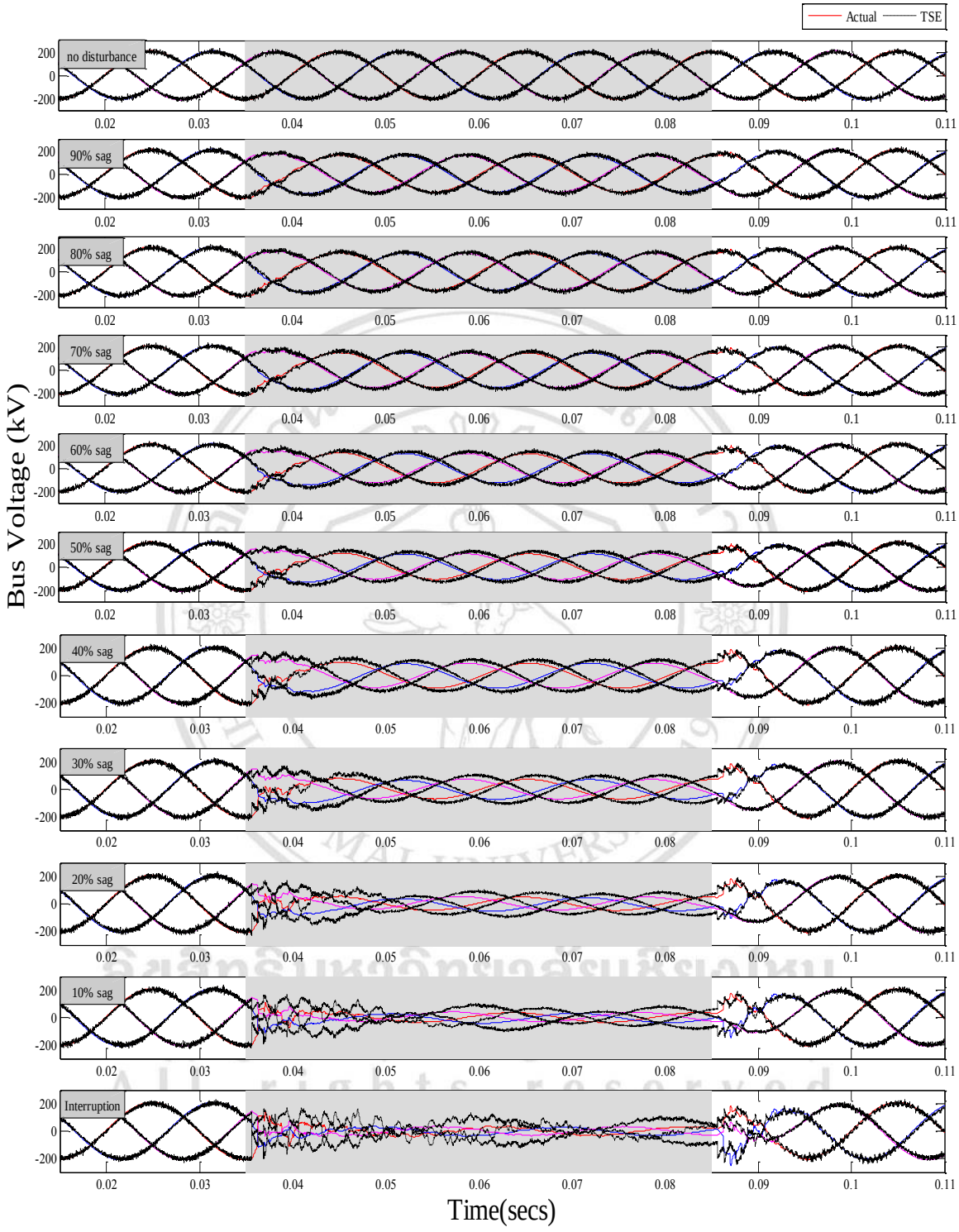

Figure B.9 Voltage at bus no.5 (three-phase disturbance, different sag with a 2% measurement noise).

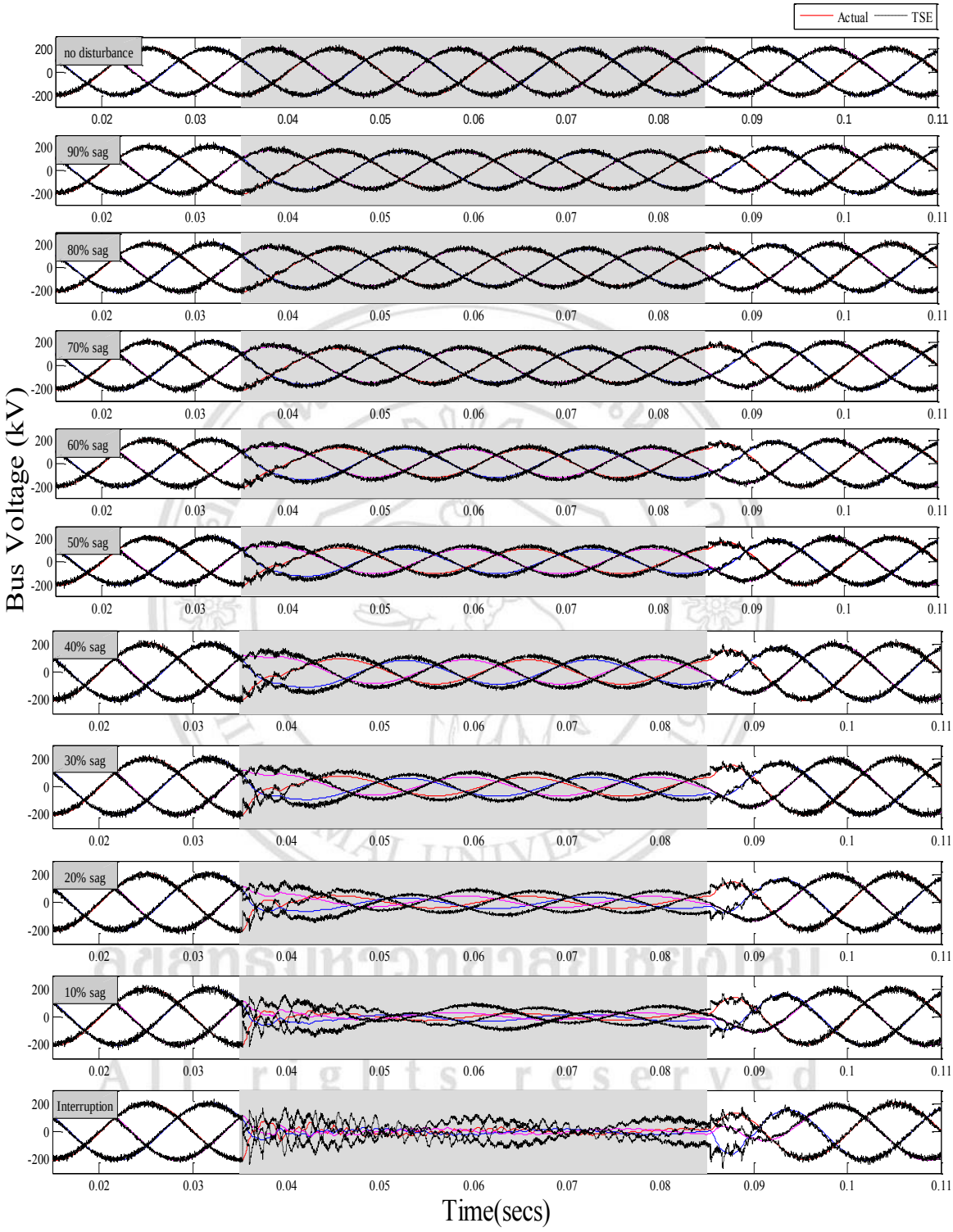

Figure B.10 Voltage at bus no.7 (three-phase disturbance, different sag with a 2% measurement noise).

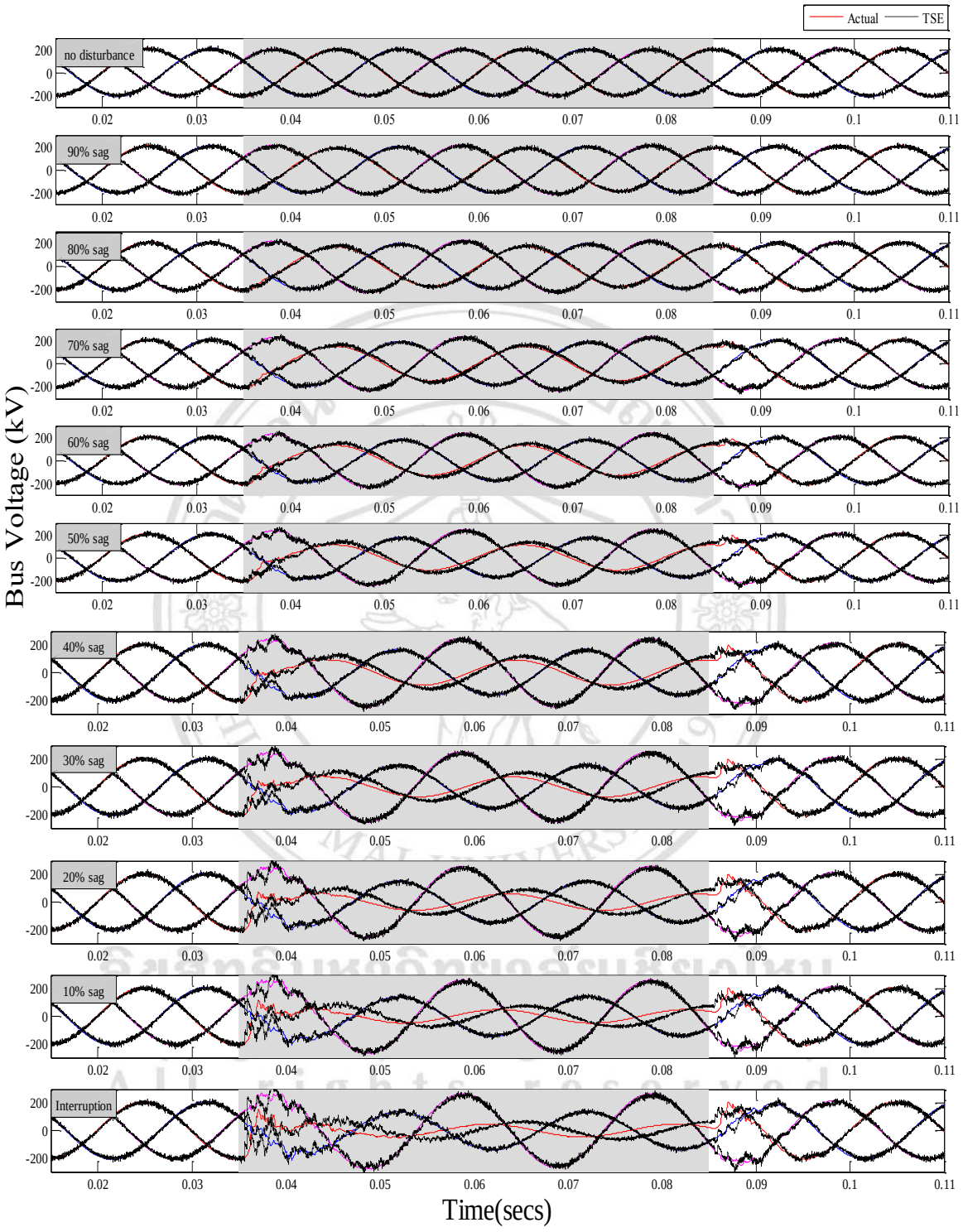

Figure B.11 Voltage at bus no.5 (single-phase disturbance, different sag with a 2% measurement noise).

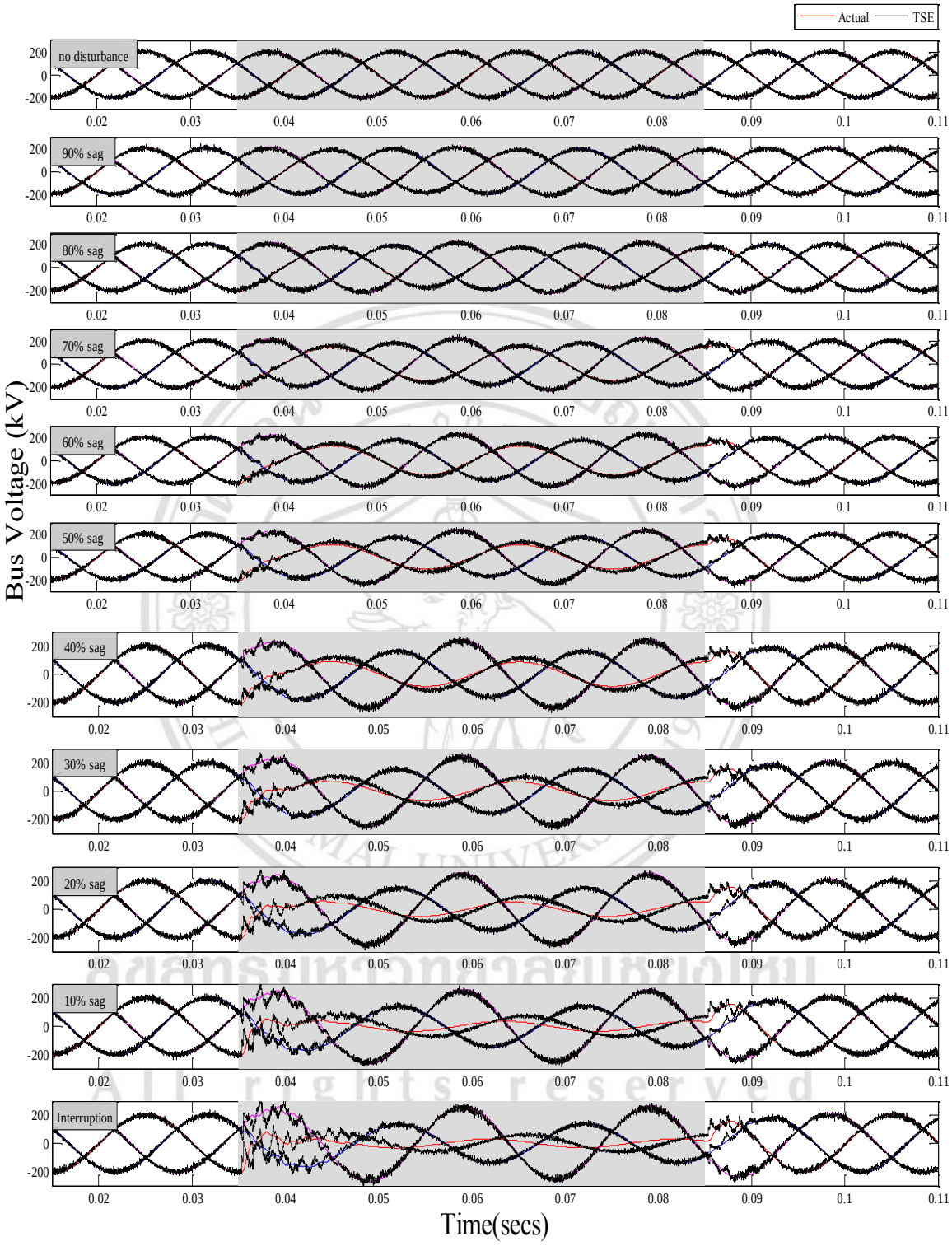

Figure B.12 Voltage at bus no.7 (single-phase disturbance, different sag with a 2% measurement noise).

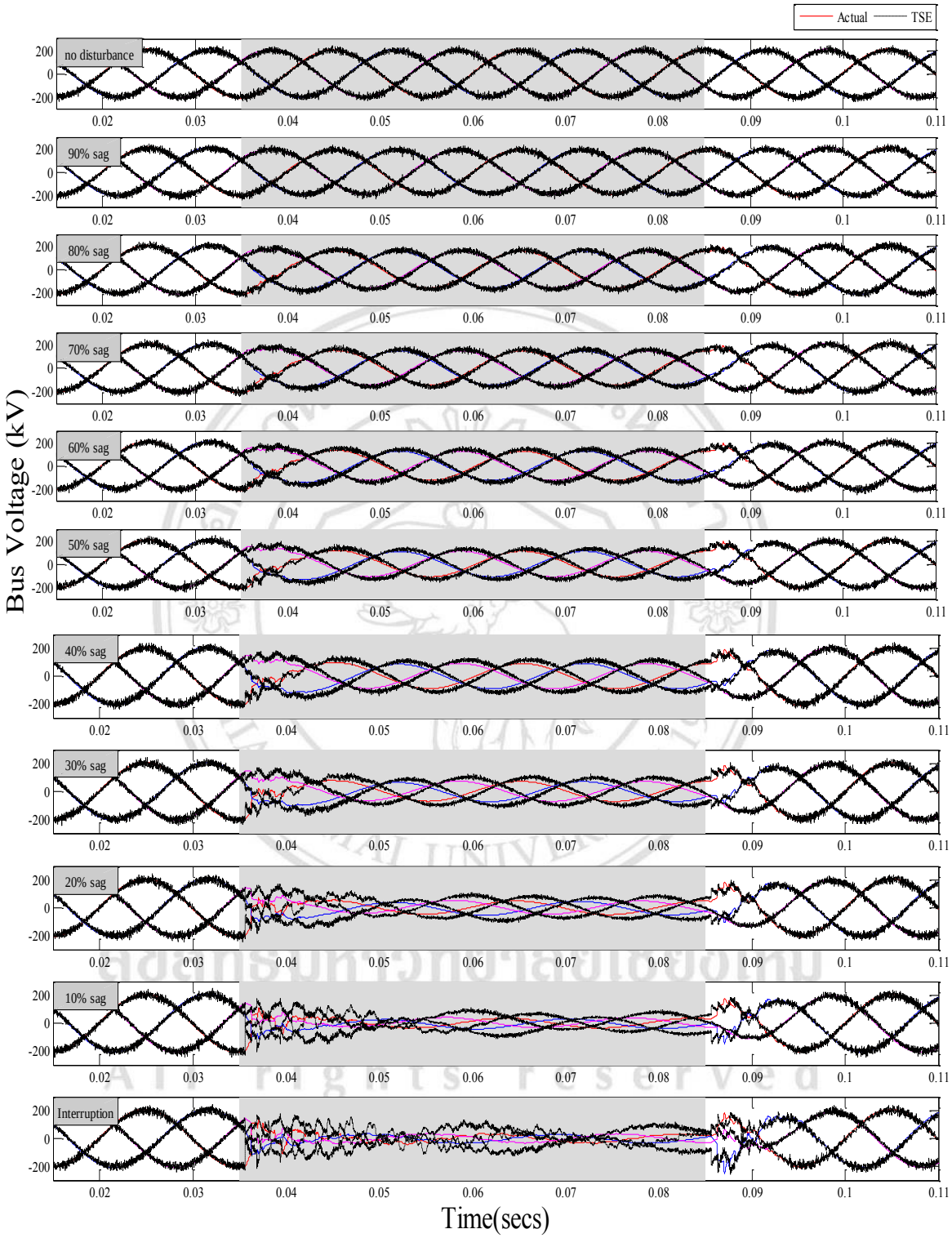

Figure B.13 Voltage at bus no.5 (three-phase disturbance, different sag with a 3% measurement noise).

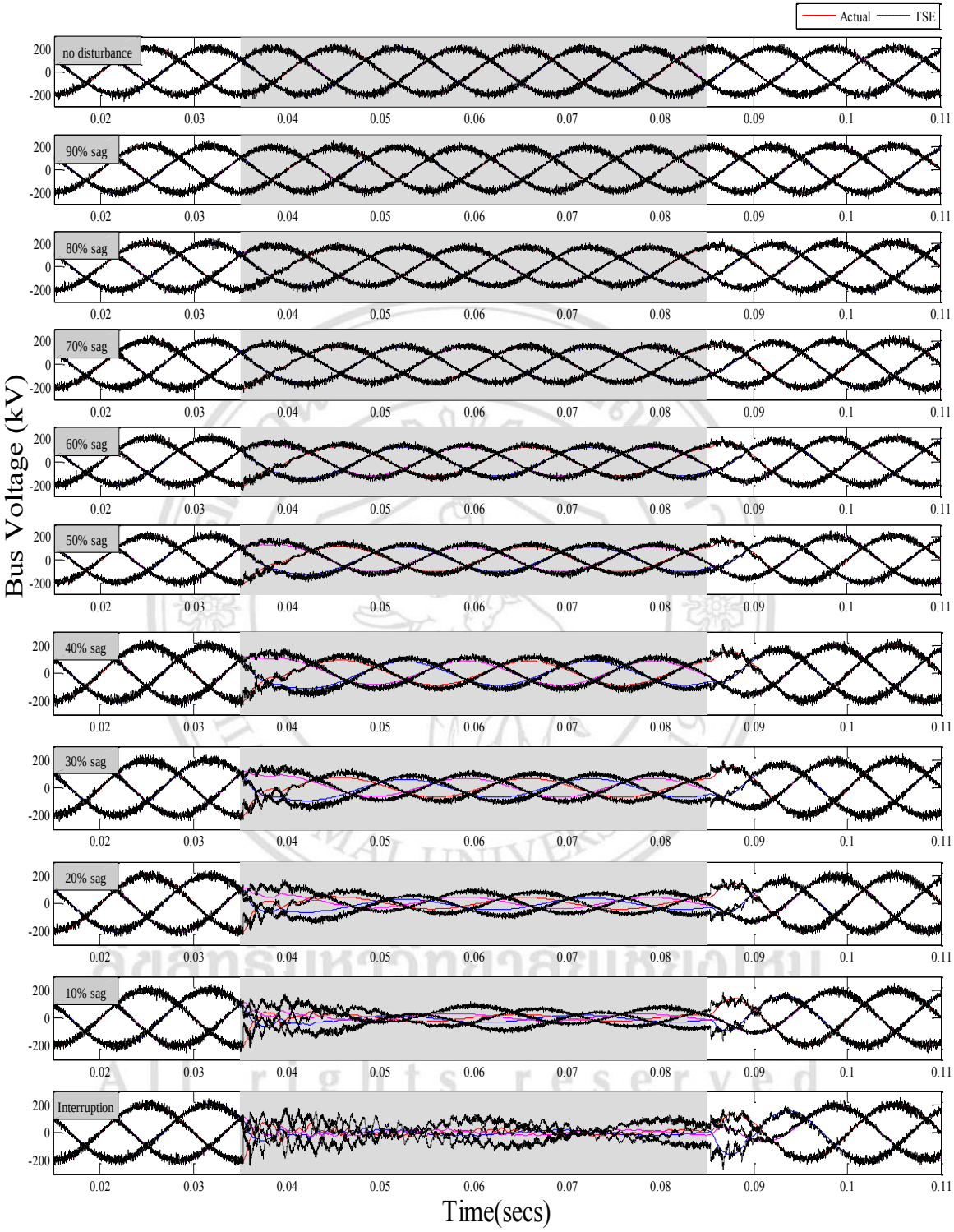

Figure B.14 Voltage at bus no.7 (three-phase disturbance, different sag with a 3% measurement noise).

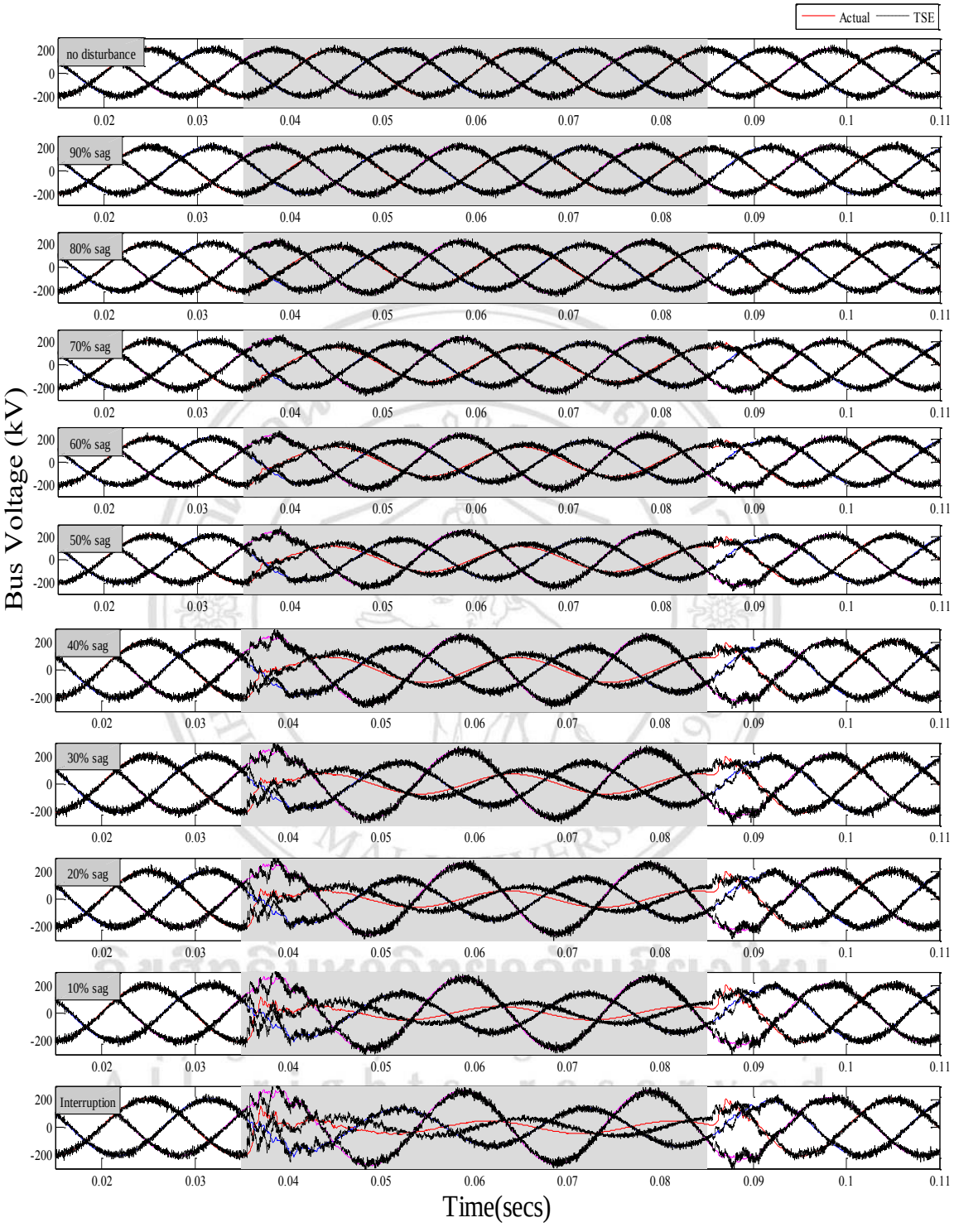

Figure B.15 Voltage at bus no.5 (single-phase disturbance, different sag with a 3% measurement noise).

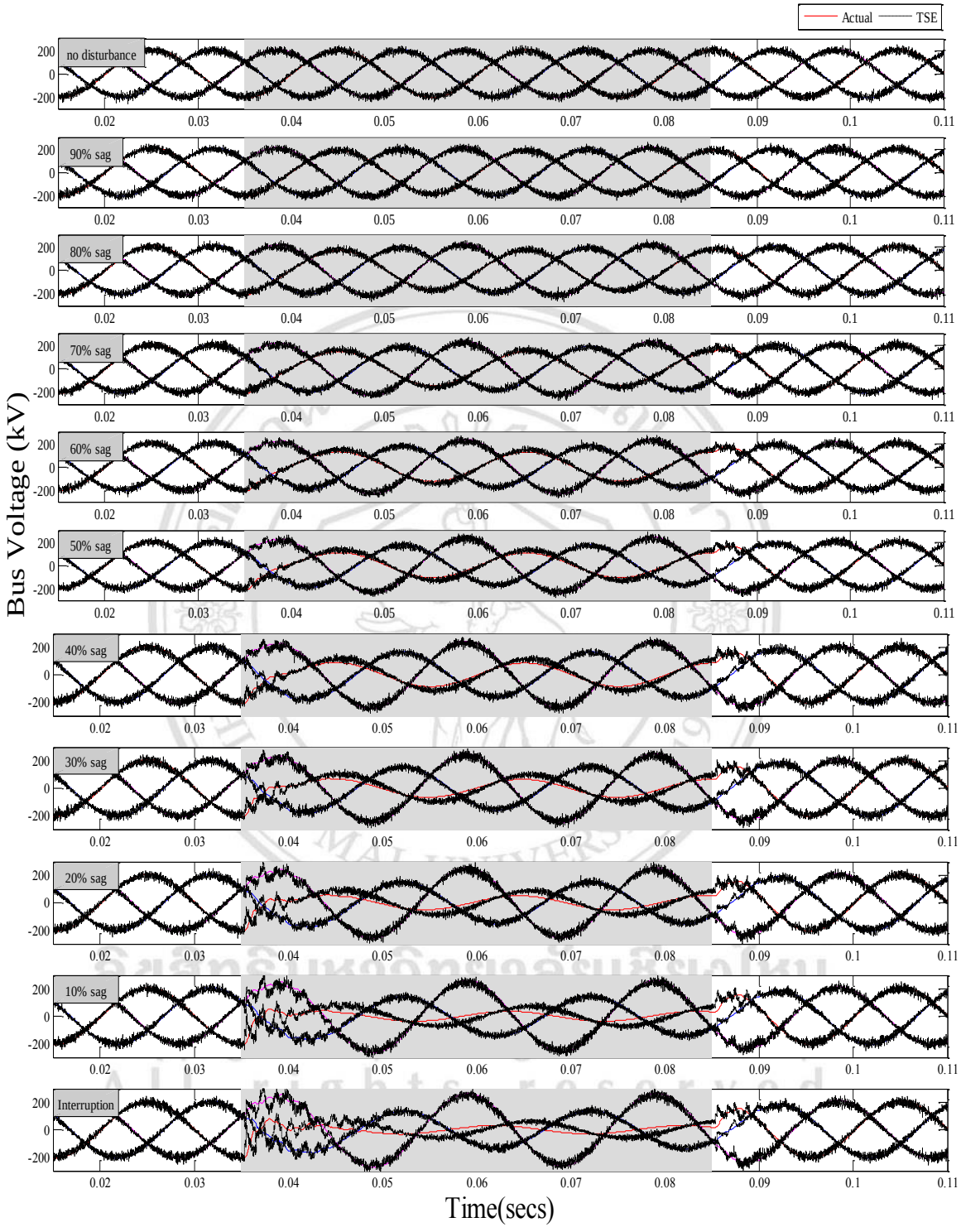

Figure B.16 Voltage at bus no.7 (single-phase disturbance, different sag with a 3% measurement noise).

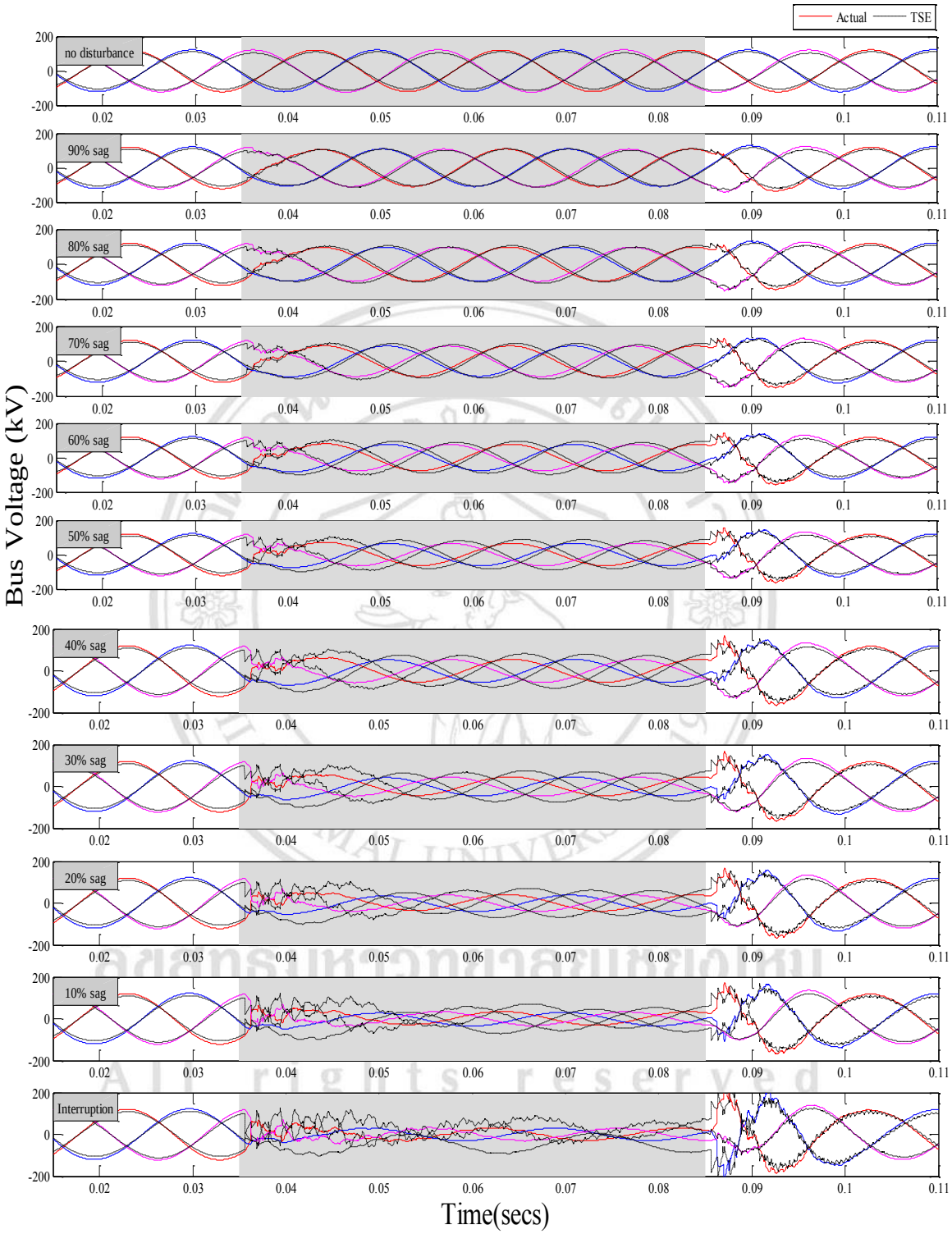

Figure B.17 Voltage at bus no.5 (three-phase disturbance: different sag with considering the saturation of transformer).

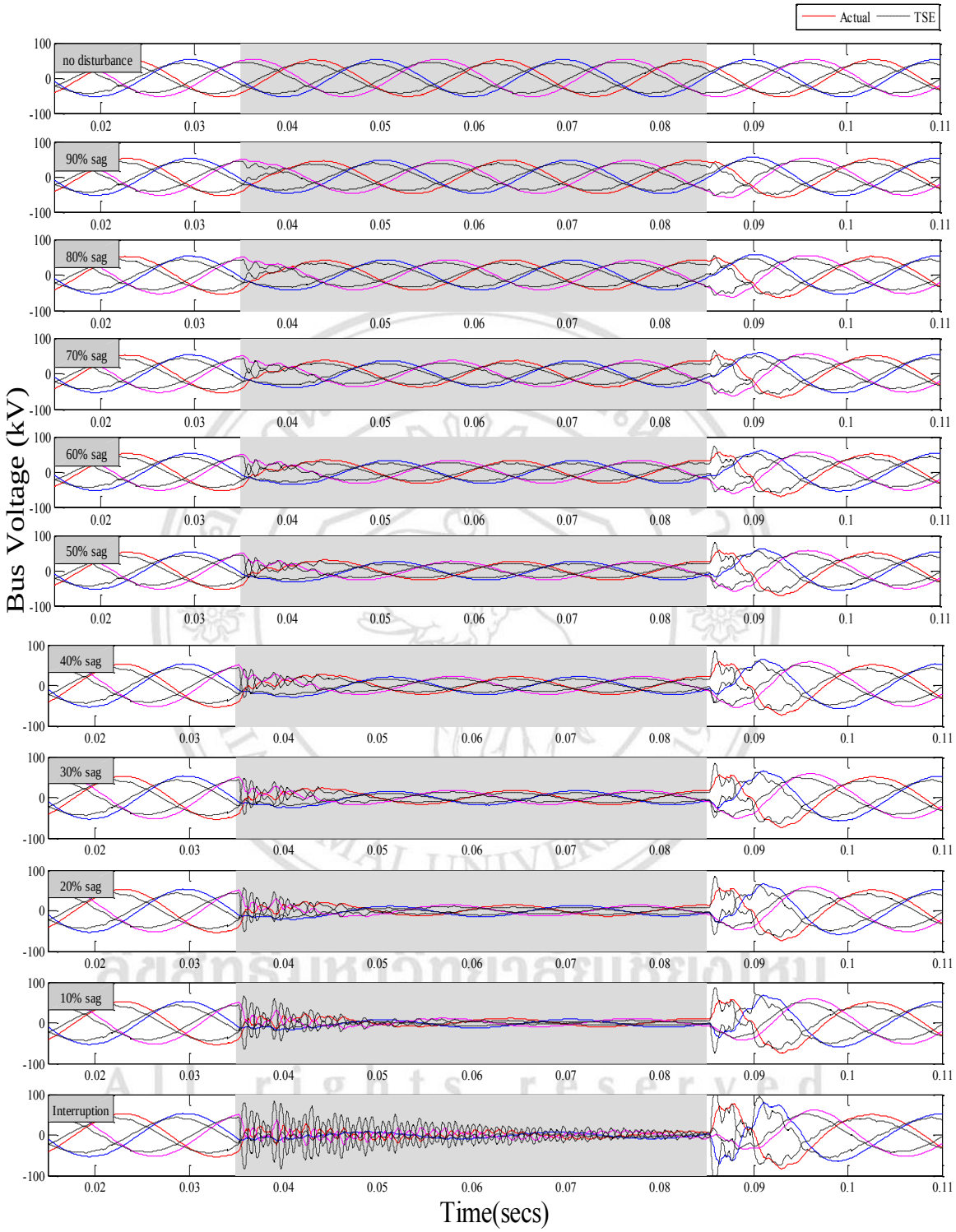

Figure B.18 Voltage at bus no.7 (three-phase disturbance: different sag with considering the saturation of transformer).

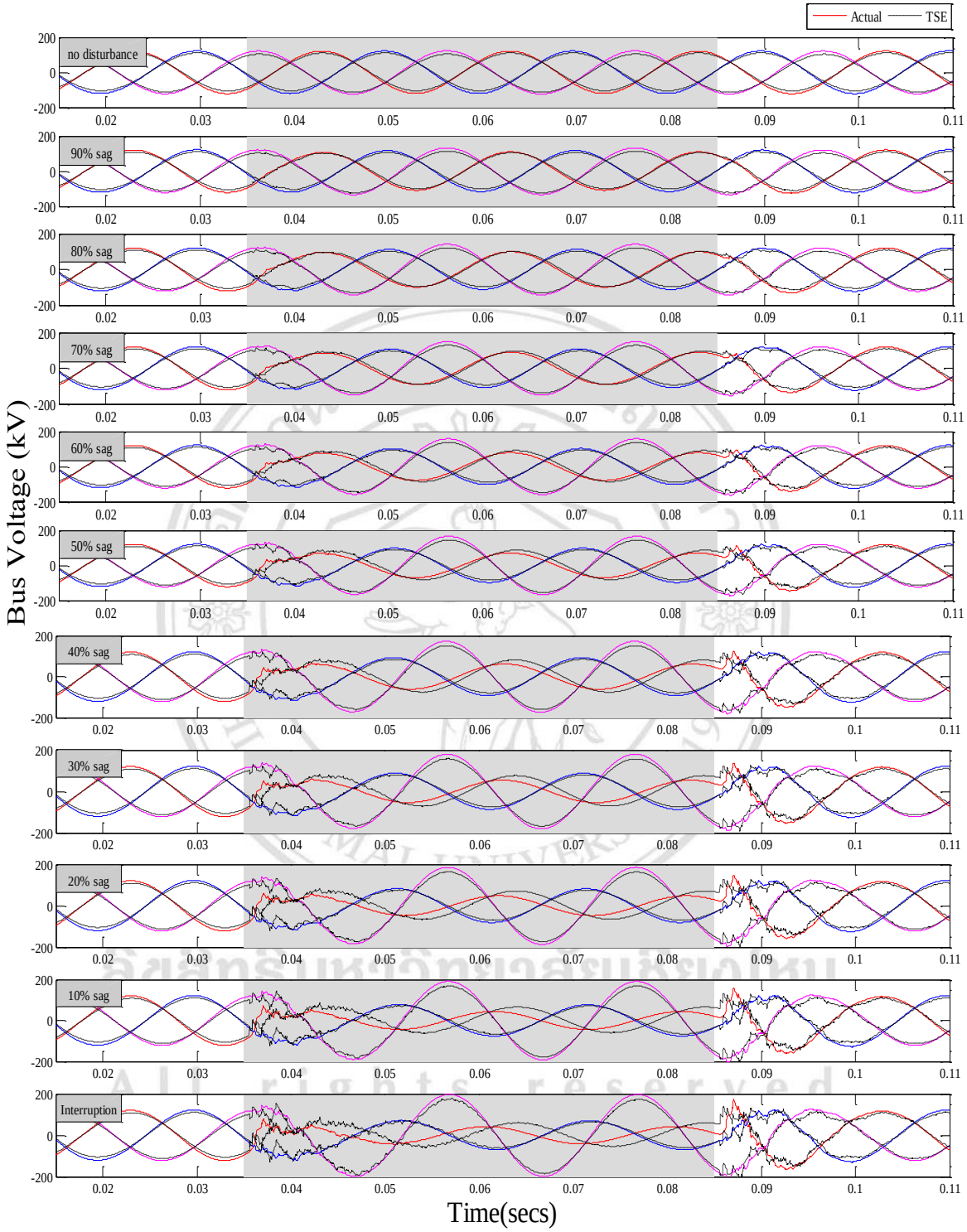

Figure B.19 Voltage at bus no.5 (single-phase disturbance: different sag with considering the saturation of transformer).

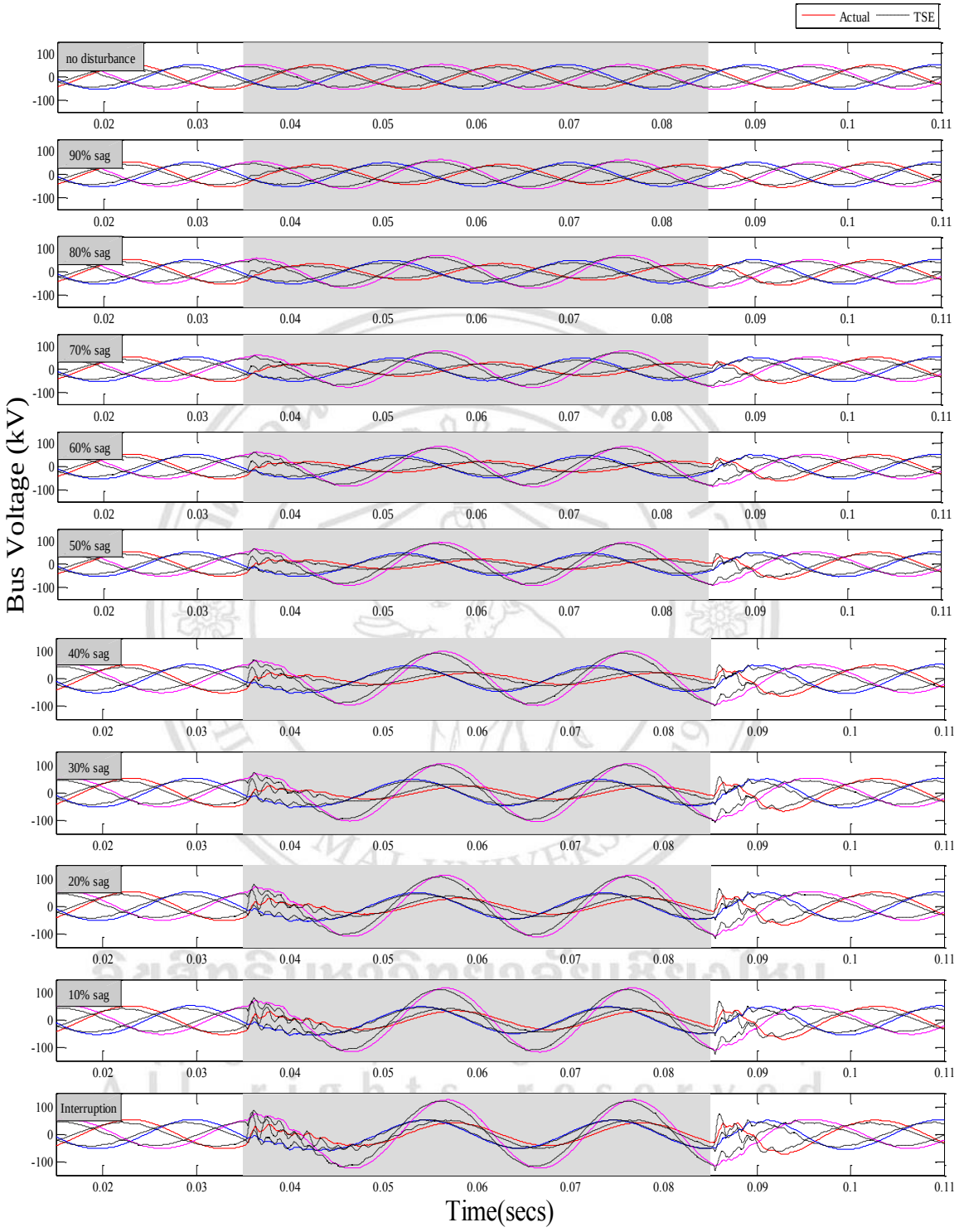

Figure B.20 Voltage at bus no.7 (single-phase disturbance: different sag with considering the saturation of transformer).

APPENDIX C

MAE Evaluation

There is another performance tool uses for evaluate the estimator which is the percentage Mean Absolute Error (%MAE) calculated by (equation 2.39)

$$\%MAE = \frac{\frac{1}{n}\sum_{i=1}^{n}\left|x_i - \hat{x}_i\right|}{peak\ voltage\ at\ nominal} \times 100 .$$

There are three cases use for consideration; TSE algorithm, TSE algorithm with noise, and TSE algorithm with nonlinear equipment (saturated transformer) as figure C.1 – C.12. Beside figure C.13 – C.16 are all phase-A of each evaluation testing.

Table C.1 List of figures of %MAE evaluation

Figure no.	Case	Type of disturbance	Location
Figure C.1	TSE	Three phase	bus no. 5
Figure C.2			bus no. 7
Figure C.3		Single phase	bus no. 5
Figure C.4			bus no. 7
Figure C.5	TSE with noise	Three phase	bus no. 5
Figure C.6			bus no. 7
Figure C.7		Single phase	bus no. 5
Figure C.8			bus no. 7
Figure C.9	TSE with saturated transformer	Three phase	bus no. 5
Figure C.10			bus no. 7
Figure C.11		Single phase	bus no. 5
Figure C.12			bus no. 7
Figure C.13	All phase-A of each evaluation testing	Three phase	bus no. 5
Figure C.14			bus no. 7
Figure C.15		Single phase	bus no. 5
Figure C.16			bus no. 7

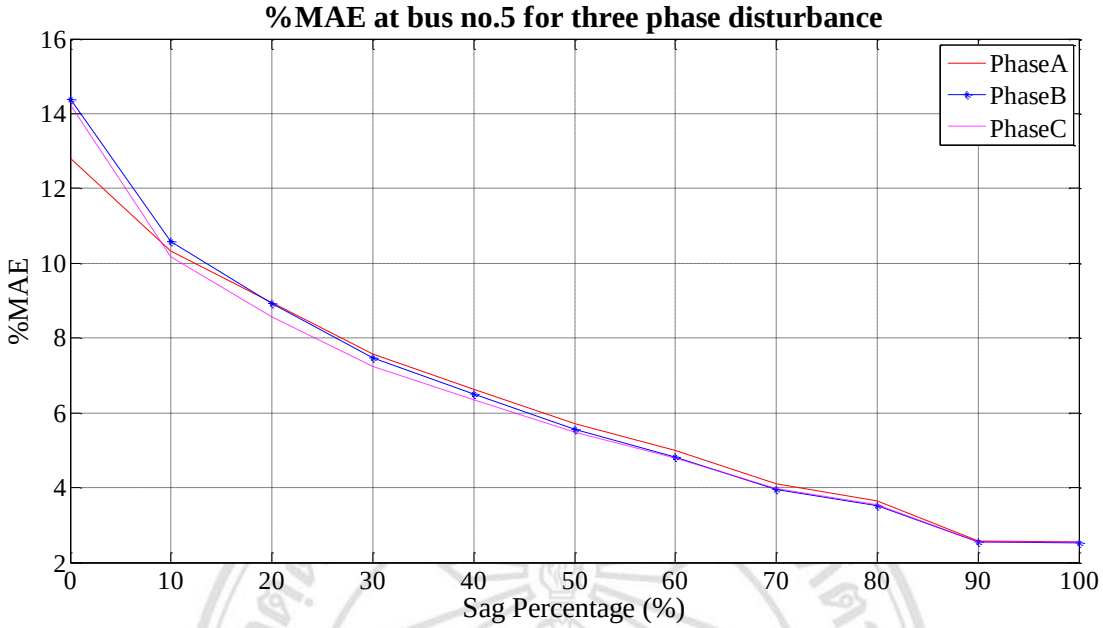

Figure C.1 %MAE at bus no.5 for three-phase disturbance.

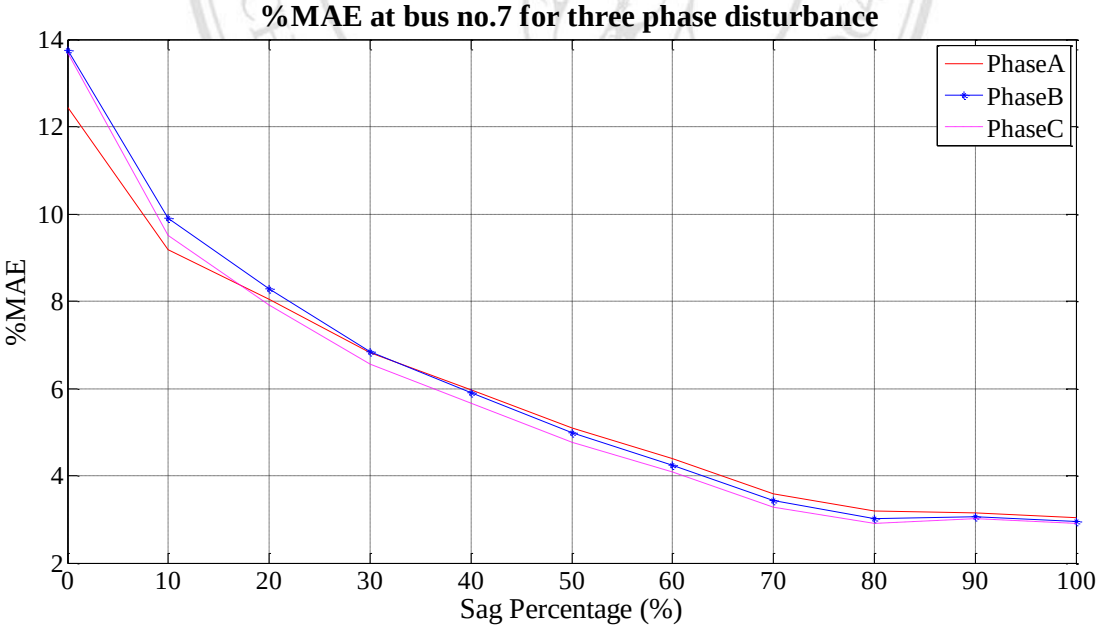

Figure C.2 %MAE at bus no.7 for three-phase disturbance.

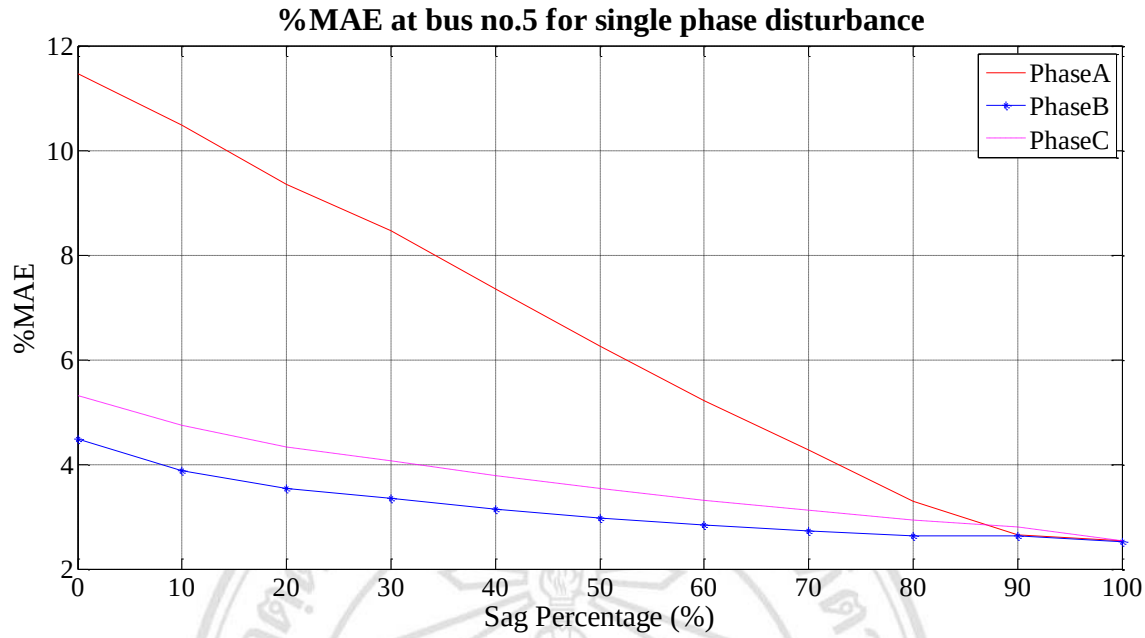

Figure C.3 %MAE at bus no.5 for single-phase disturbance.

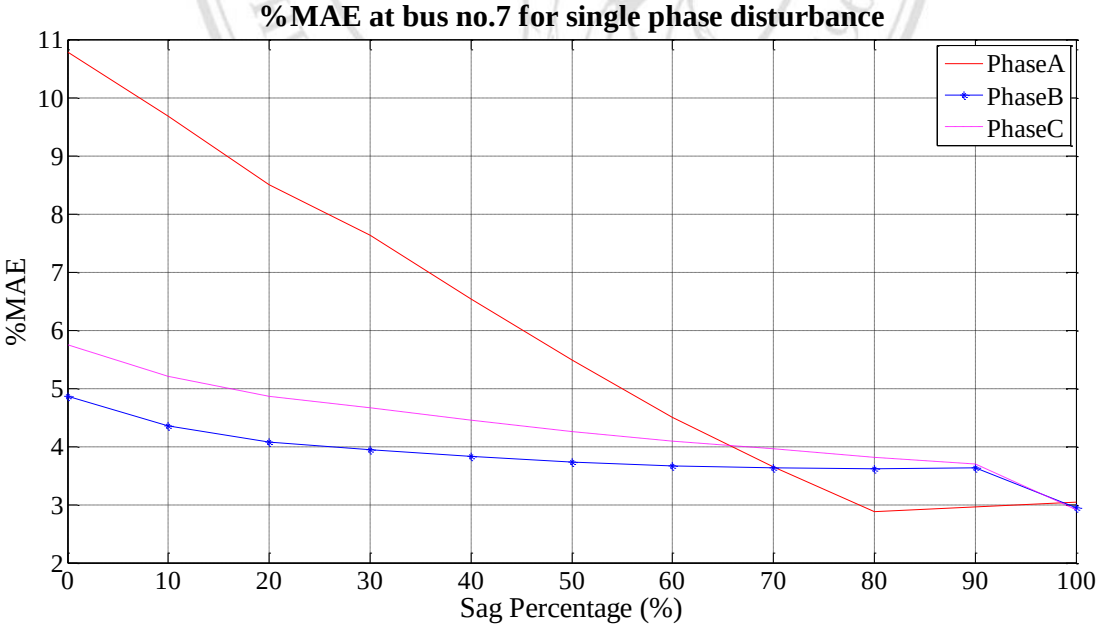

Figure C.4 %MAE at bus no.7 for single-phase disturbance.

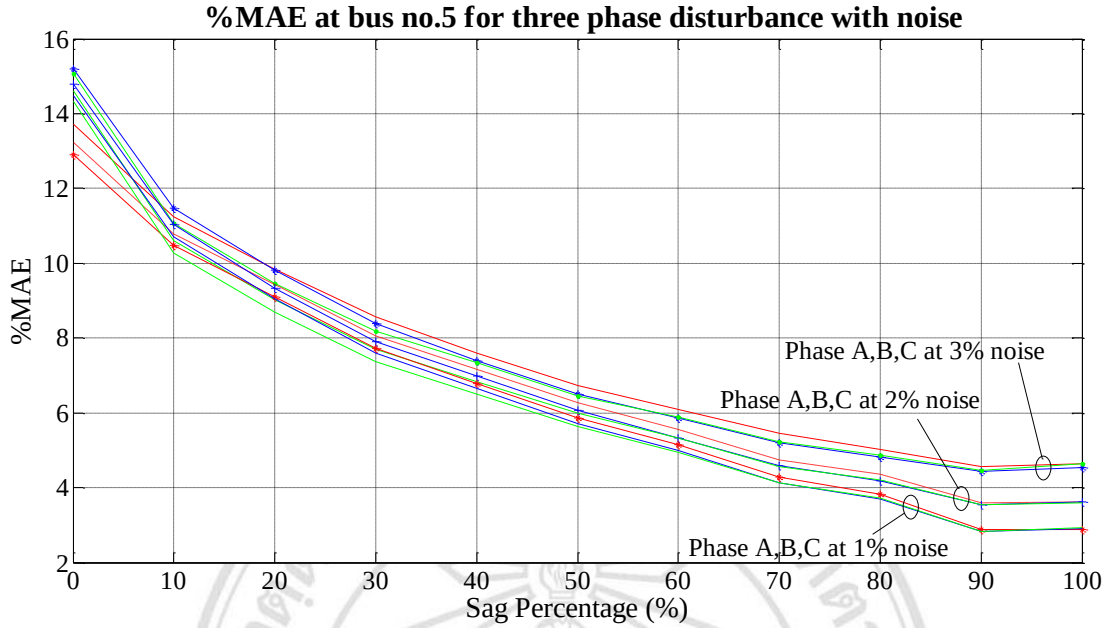

Figure C.5 %MAE at bus no.5 for three-phase disturbance with measurement noise.

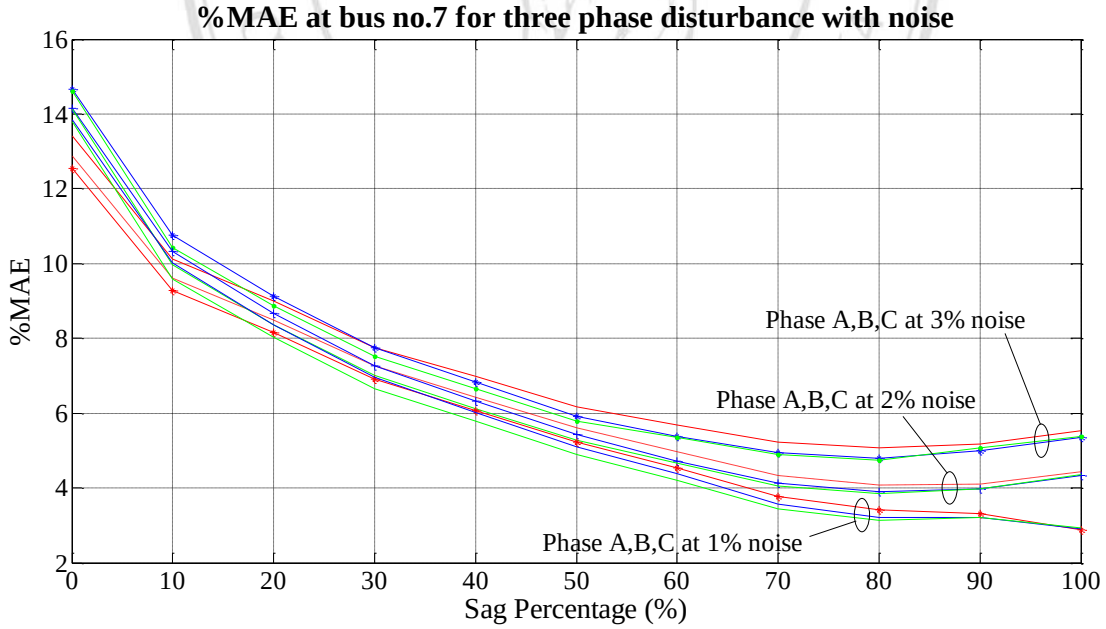

Figure C.6 %MAE at bus no.7 for three-phase disturbance with measurement noise.

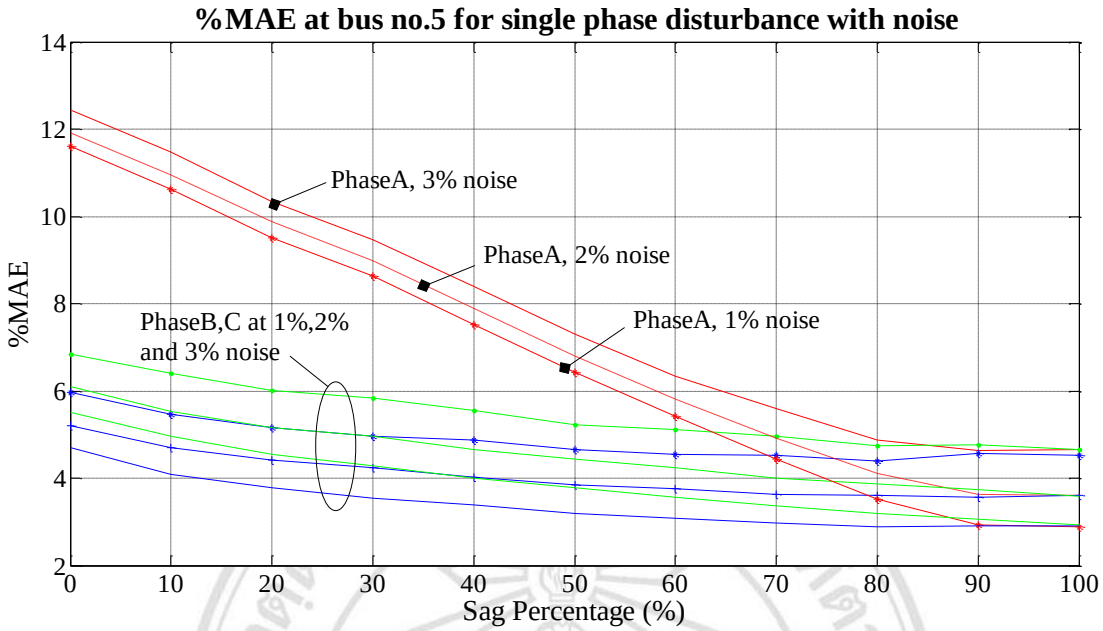

Figure C.7 %MAE at bus no.5 for single-phase disturbance with measurement noise.

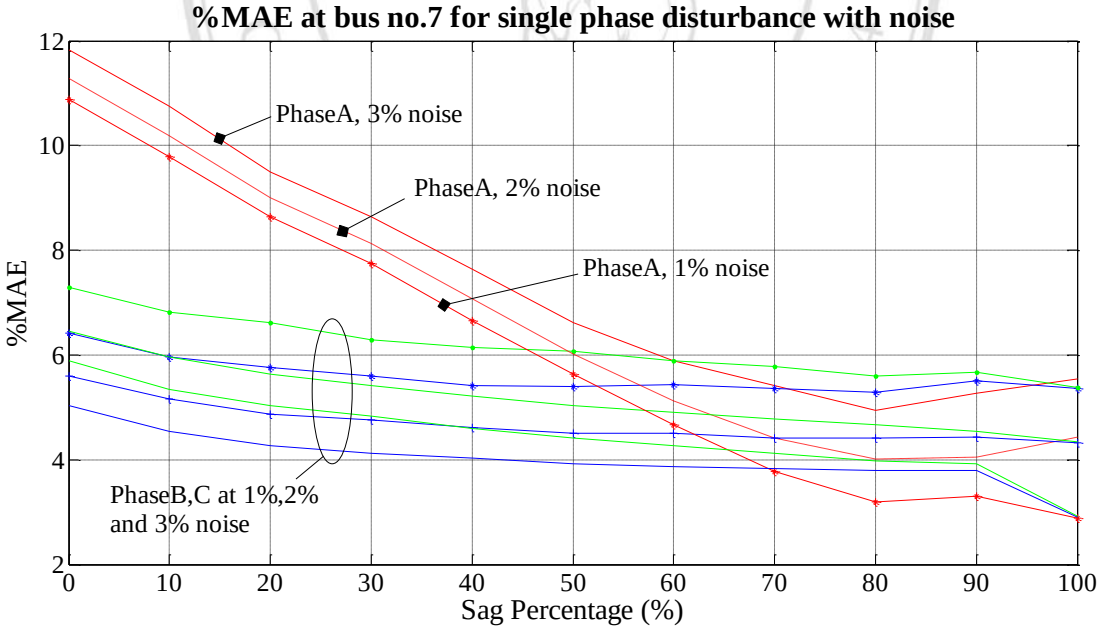

Figure C.8 %MAE at bus no.7 for single-phase disturbance with measurement noise.

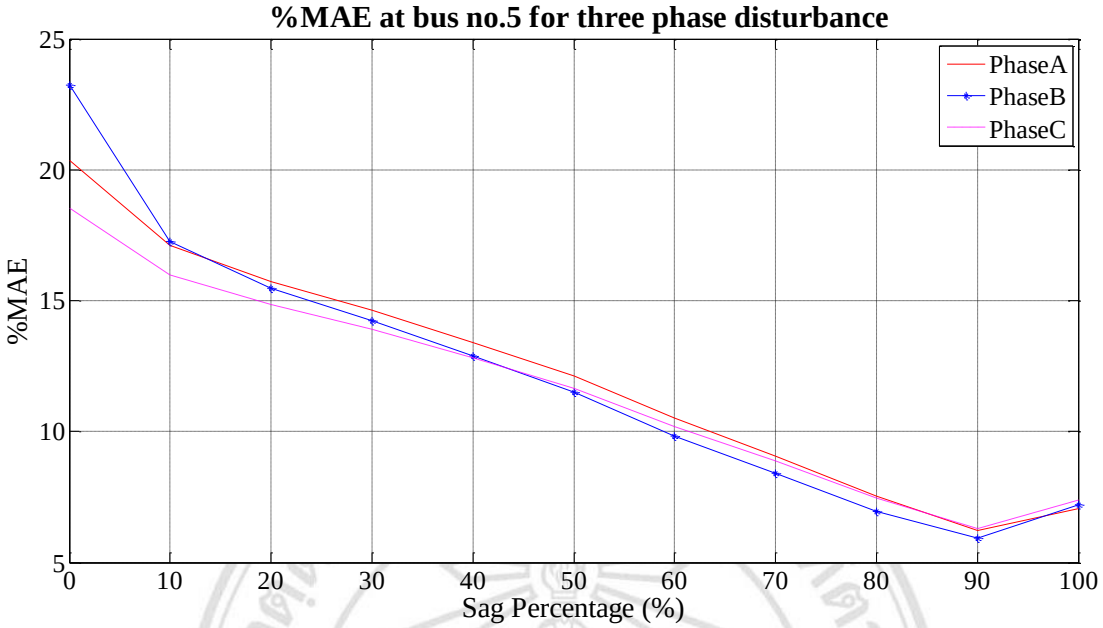

Figure C.9 %MAE at bus no.5 for three-phase disturbance with considering the saturation of transformer.

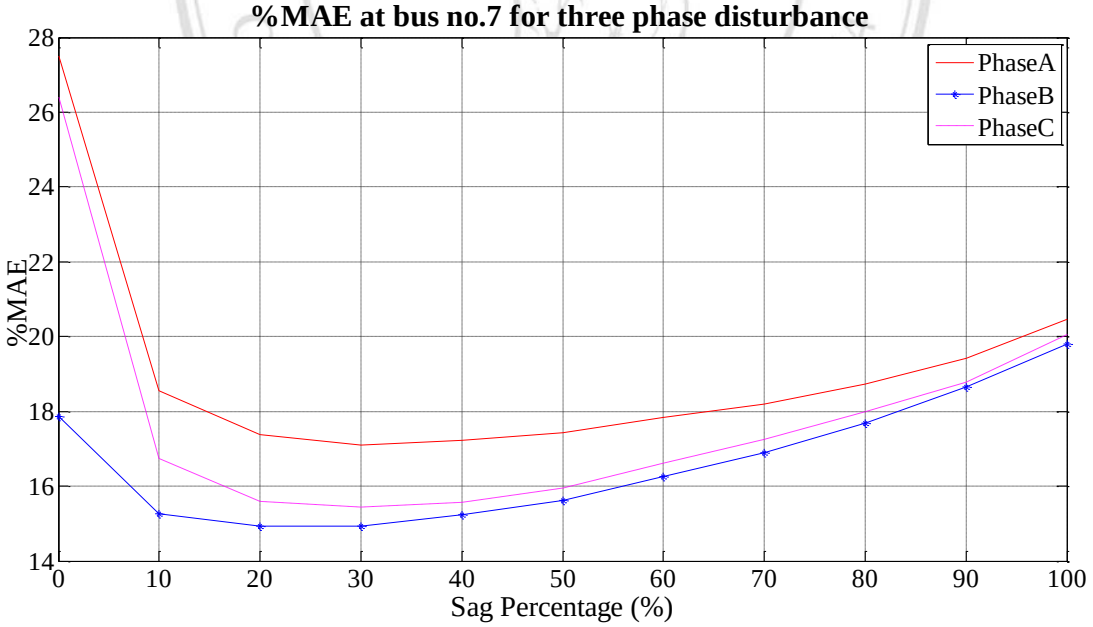

Figure C.10 %MAE at bus no.7 for three-phase disturbance with considering the saturation of transformer.

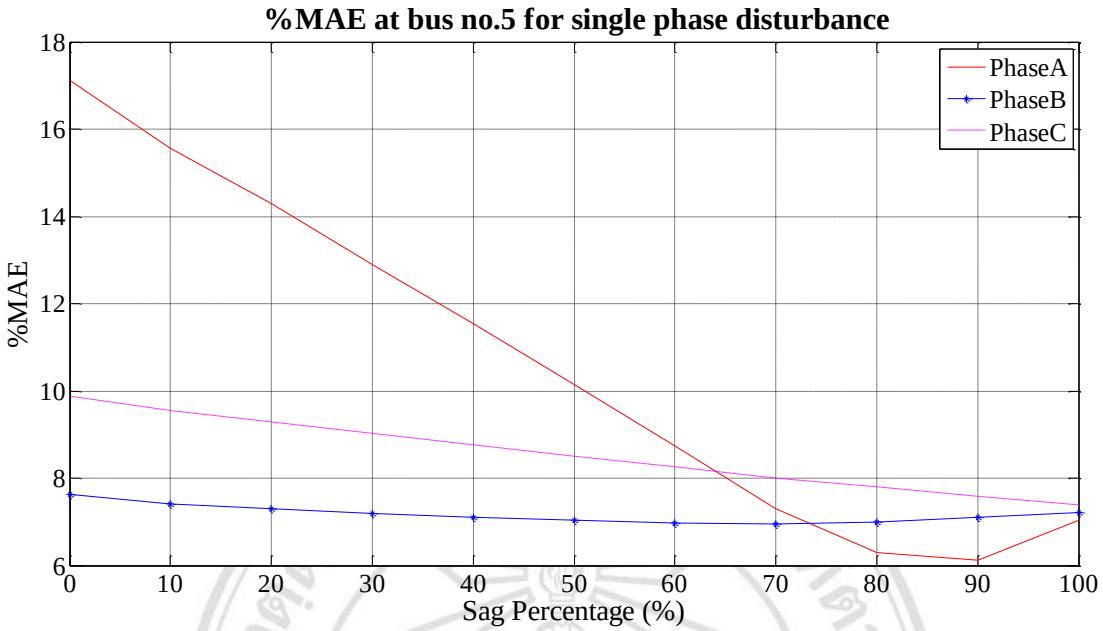

Figure C.11 %MAE at bus no.5 for single-phase disturbance with considering the saturation of transformer.

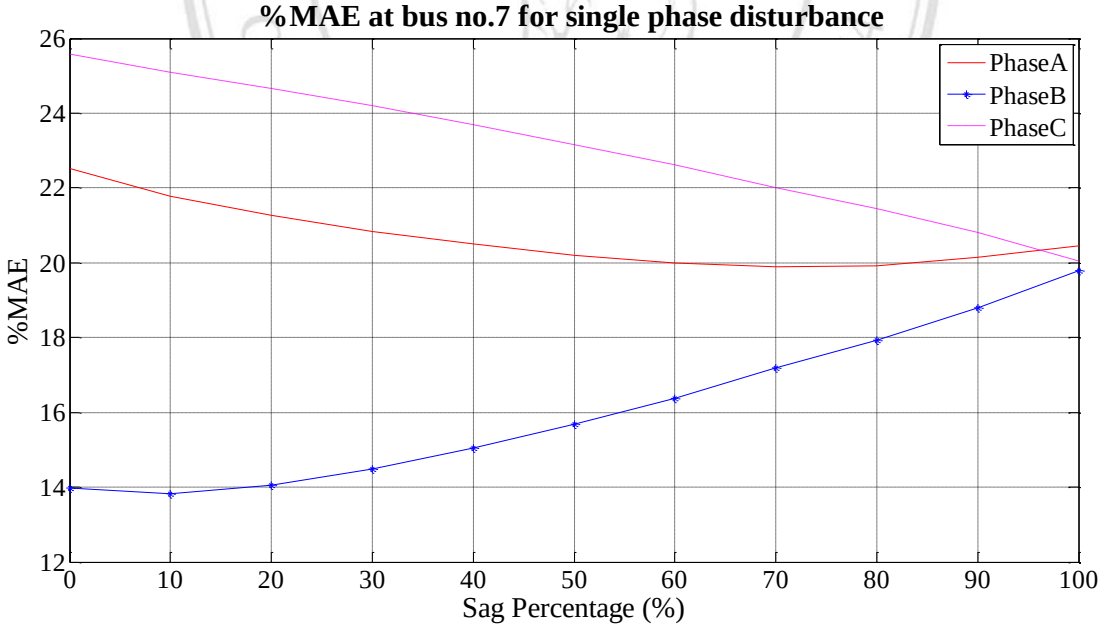

Figure C.12 %MAE at bus no.7 for single-phase disturbance with considering the saturation of transformer.

CURRICULUM VITAE

Author's Name	Mr. Naret Suyaroj
Date/Year of Birth	6 August 1976
Place of Birth	Chiang Mai Province, Thailand
Education	Academic Year 1997 Bachelor of Engineering (Electrical), Chiang Mai University.
	Academic Year 2007 Master of Engineering (Electrical), Chiang Mai University.
Publications	[1] Wongsathan C., and Suyaroj N., "Neural Networks Solutions of Thermistor Problem Tuned by Genetic Algorithms and Gradient Descent Method," IASTED International Conference on Artificial Intelligence and Applications (AIA 2008), Innsbruck, Austria, 11-13 Feb 2008.
	[2] Suyaroj N., Theera-Umpon N., and Auephanwiriyakul S., "Power Prediction in Reverse Link for Mobile DS/CDMA Systems Using Support Vector Regression," The 2008 Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology International Conference (ECTI-CON 2008), Krabi, Thailand, 14-17 May 2008, 569-572.
	[3] Suyaroj N., Theera-Umpon N., and Auephanwiriyakul S., "A Comparison of NN-Based and SVR-Based Power Prediction for Mobile DS/CDMA Systems," The International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS 2008), Bangkok, Thailand, 8-11 Feb 2009.
	[4] Suyaroj N., Jaidang K., and Kanitpanyacharoean W., "Potassium Chlorate Compound Concentration Meter by Using Light Transmittance Property," The 10th Annual Conference of

Thai Society of Agricultural Engineering, Suranaree University of Technology, Nakhon Ratchasima,Thailand, 1-3 April 2009.

[5] Suyaroj N., Premrudeepreechacharn S., and Watson N. R., "Power System Transients State Estimation," IEEE Region (R10) 2013 TENCON –SPRING, Sydney, Australia, 17-19 April 2013.

[6] Suyaroj N., Premrudeepreechacharn S., and Watson N. R., "Transients State Estimation with Measurement Noise," The 2015 Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology International Conference (ECTI-CON 2015), Hua Hin, Thailand, 24-26 June 2015.

Experience

Design Engineer, LTEC Ltd., Northern Region Industrial Estate, Lamphun, 1998-2002.

Lecturer, Department of Electrical Engineering, Faculty of Engineering, North-Chiang Mai University, 2002-Present.