SHORT TERM VOLTAGE STABILTY ANALYSIS OF AN AGGREGATED INDUSTRIAL LOAD

L. K. Obiri, J. M. Kinyua and C. M. Muriithi
School of Electrical, Electronic and Information Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: lynne.obiri@gmail.com

Abstract
Environmental constraints have limited expansion of transmission line networks. And with power systems being operated close to their security limits, the likelihood of voltage collapses occurring has increased. In most industries, the induction motor forms about 50% of the total electric load and this call for a thorough analysis of their effects on the whole power system. After a disturbance, stalling can occur if the electrical torque does not overcome the mechanical load, causing further voltage drop and eventually voltage collapse. An aggregate motor model is simulated in MATLAB-SIMULINK. If a three phase fault is not cleared in time, the motor will decelerate continuously and eventually stall.

Key words: Voltage stability, induction motor, aggregate, voltage collapse, power system

1.0 Introduction

Power system voltage stability has previously been analysed using static load models. But due to the dynamic nature of the power system, dynamic load modelling is preferred when there is need to analyse the different stages of events that occur during, before and after voltage collapse. Induction motors constitute more than 50% of the dynamic industrial load [2]. They are considered as the main dynamic industrial load and hence their impact on the power system should be analysed. Being constant power loads, their active power consumption restores to a constant value after a disturbance. They thus draw high reactive currents causing further voltage drop in the power system. This can result in stalling of the motors, voltage instability and eventual voltage collapse [3].
To restore the voltage levels to normal after a disturbance, AVRs are included in the excitation system. But these devices introduce a negative damping torque. Thus PSS are included in the excitation system to dampen the LFO introduced by the AVRs. FLPSS are a group of PSS that have simplified control design and implementation. But their effect on the power system can result in induction motor stalling and eventual voltage collapse can occur.

Various aggregation methods have been discussed in different literature. In [4], the transformer type equivalent circuit is used to aggregate the induction motors, while in [5] the no load and locked rotor conditions are used to determine the parameters of the aggregate motor. Authors in [6] use a probabilistic approach to aggregate identical induction machines connected to a bus. In [7], the aggregate model is obtained using the standard specification of the motors. Per unit aggregation is used in [8] to represent the group of induction motors. Methods in [4] and [5] are compared to determine the superior aggregation method.This paper examines the effect of induction motors and on the short term voltage stability of a power system. The simulation is carried out in MATLAB – SIMULINK.

2.0 Methodology

The first stage involved determining which proposed method of aggregation of induction motors was a closer representation of the individual motors. Data from five individual motors as stated in [5] were aggregated using two methods. Table one represents the parameters of the individual motors.

Table 1: Individual motor parameters

Rs	Xs	Rr	Xr	Xm	Hp	rpm
4.86	2.67	1.84	2.67	84.68	3	1760
1.48	0.18	0.31	0.18	24.89	15	1765
0.73	0.16	0.16	0.16	14.96	30	1765
0.42	0.15	0.14	0.15	9.47	50	1750
0.25	0.1	0.08	0.1	3.97	100	1740

The first method, agg1, was proposed in [5] by Karakas et al and involved using no load and lock rotor conditions to determine the aggregate parameters. The second method, agg 2, was proposed by Pillay et al in [4] and it involved transformer method of aggregation. Simulations were carried out in Matlab-Simulink for the individual motors and the two aggregate methods. The total simulation time was 0.5 seconds with the circuit breaker opening and closing at 0.25 and 0.3 seconds. Graphs of mechanical power, reactive power and current were plotted against time.

From Figure 1, Figure 2and Figure 3, it was concluded that the superior method of aggregation was that proposed in [5]. The aggregate model of the induction motors was then introduced in the 16 bus power system. The aggregate IM replaced part of the static load in bus 16. The total load was 150MW with the static load composing of 145MW and the dynamic load amounting to 5MW.A temporary three phase fault was introduced into the system at times 14/60 and 17/60 seconds with the circuit breaker opening and closing at 0.25 and 0.3 seconds. The total duration of the simulation was 0.5 seconds.

Graphs of mechanical power, reactive power, voltage, current and electrical torque were plotted against time.

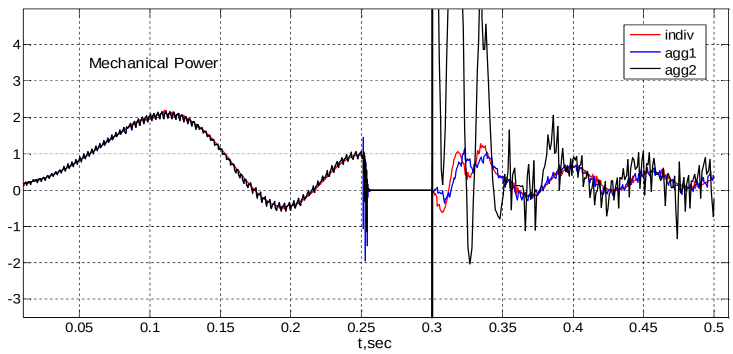

Figure 1: Mechanical power

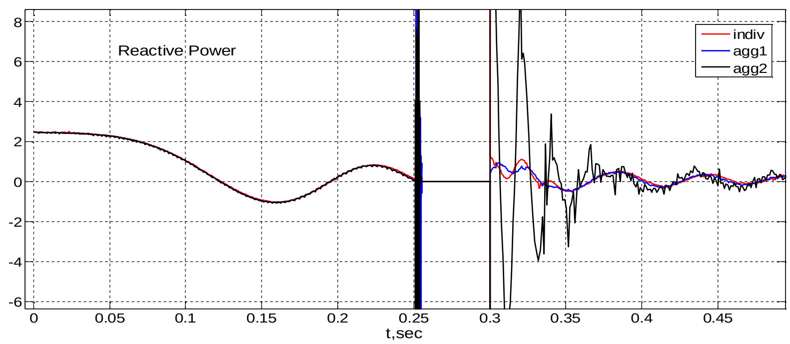

Figure 2: Reactive power

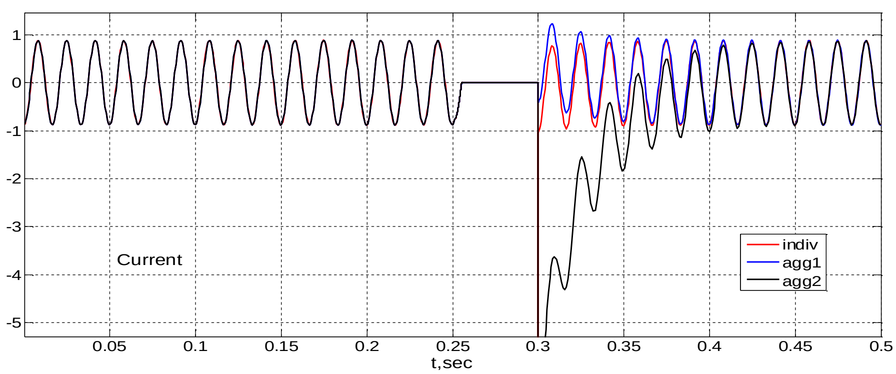

Figure 3: Current phase A

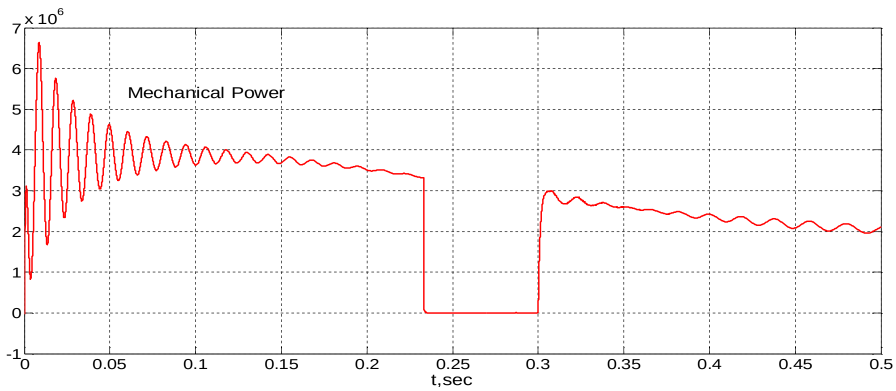

Figure 4: Mechanical power

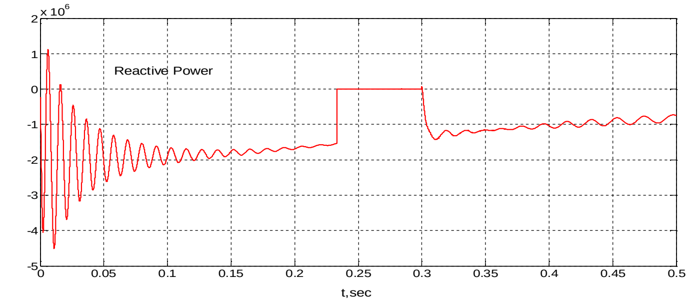

Figure 5: Reactive power

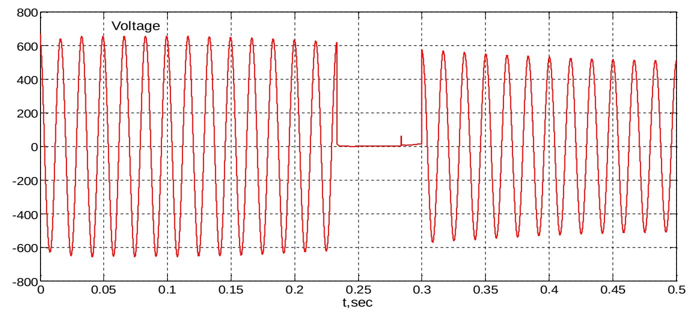

Figure 6: Stator voltage phase A

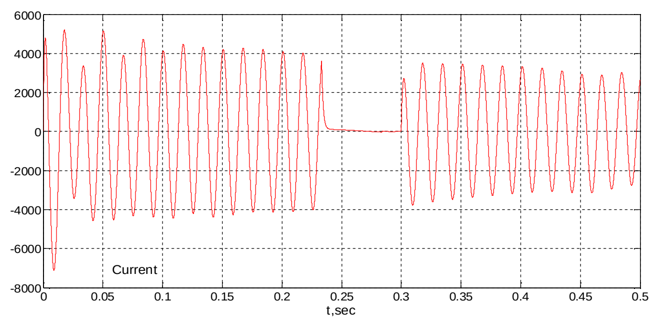

Figure 7: Stator current phase A

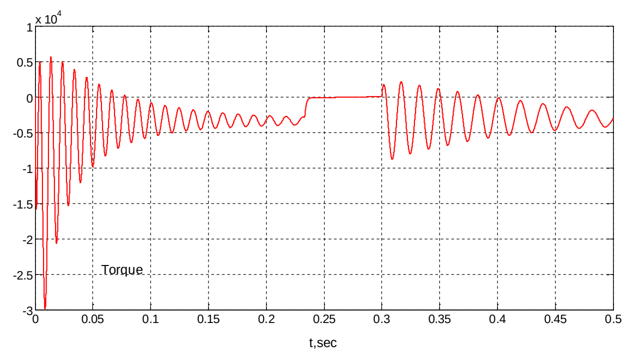

Figure 8: Rotor electrical torque

3.0 Conclusion

From the investigation carried out, induction motors have an impact in the short term voltage stability of the power system. Being constant power loads, they draw high reactive currents after a disturbance and this can result in eventual voltage collapse. There is also need for more accurate aggregation methods for induction motors.

References

Repo Sami *On-Line Voltage Stability Assessment of Power System-An Approach of Black-Box Modelling*. Tampere, Tampere University of Technology, 2001.

Jose, E., Onoda, P., Fabio, M., DaSilva, Osvaldo, S. and Julio Cesar, R. B. (2007). Expanding an Industrial Load Model for Short-Term Voltage Stability Analysis. *International Journal of Emerging Electric Power Systems*, pp. 1-18.

Emmanuel , G. Potamianakis and Costas, D. V., Fellow, IEEE. (2006). *Short-Term Voltage Instability:* Effects on Synchronous and Induction Machines. IEEE *Transactions On Power Systems*, **21**(2): pp. 791-798.

Pillay, P., Sabur, S. M. A. and Haq, M. M. (1997). A model for induction motor aggregation for power system studies. *Electric Power Systems Research,* **42**: pp. 225-228.

Arif, K., Fangxing, L. and Sarina, A. (2009). Aggregation of Multiple Induction Motors using MATLAB-based Software Package. *Knoxville IEEE*, pp. 1-6.

Aleksander, M., Stankovic, Bernard, C. L. (1996). A Probabilistic Approach to Aggregate Induction Machine Modeling. *IEEE Transactions on Power Systems,* **11**(4).

Louie, K.W. and Wilson, P. (2006). Aggregation of Induction Motors based on their Specifications. *IEEE CCECE/CCGEI.* 2006.

Banyatnopparat, T. and Kunakom, A. (2009). Representation of a Group of Three-phase Inducion Motors Using Per Unit Aggregation Model. International Conference on Power Systems Transients. pp. 1-7.

Hossein Zadeh, N. and Kalam, A. Performance of a Self-Tuned Fuzzy-Logic Power System Stabiliser in a multimachine System.

Neeraj Gupta, S. And Jain, K.(2010). Comparative Analysis of Fuzzy Power System Stabilizer Using Different Membership Functions. *International Journal of Computer and Electrical Engineering,* Vol. **2**:pp. 1793-8163.

Mureithi, C. M., Ngoo, L. M. And Nyakoe, G. N. Investigating the Impact of a Fuzzy Logic Power System Stbilizer in a Multi Machine System with an Induction Motor Load. Department of Electrical and Electronics Engineering, Jomo Kenyatta University of Agriculture & Technology. pp. 1-6.

Menniti, D., Burgio, A., Pinnarelli, A. And Sorrentino, N. (2003). Synchronizing Fuzzy Power System Stabilizer and Fuzzy FACTS Device Stabilizer to damp electromechanical oscillations in a multi-machine power system. IEEE Bologna Tech Conference.