

## Impact of Temporary Voltage Grid Disturbance to Running Speed of Three Phase Induction Motor

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### ABSTRACT

In the electric power system, especially the distribution system, several disturbances may occur. Voltage grid disturbance is an important power quality problem on the distribution side especially for industry with dynamics loads consisting many three phase electric motors. As the voltage grid disturbance appears, the electrical load especially an induction motor is expected to keep running on the rated speed. This motor condition is also well known as ride-through capability. In this article, the influences of temporary voltage grid disturbances are analysed to know the running speed of an induction motor based on difference in moment of inertia and give further information about the ride through capability by using PSIM simulation as an experimental tool. There are various types of voltage grid disturbance drop will be proposed. The proposed types of voltage grid disturbance to be observed are short duration sag, long duration sag, momentary swell and momentary interruption. The experiential conventional methods observed in the works are direct on line, wye-delta and autotransformer. The PSIM simulation results demonstrate that increasing the rotor moment of inertia from 0.4 to 0.8 enhances the dynamic resilience of the motor by reducing the average speed deviation by approximately 9.76% during a long-duration voltage sag. Meanwhile, the momentary interruption is identified as the most severe grid disturbance, as it leads to a complete loss of electromagnetic torque and consequently causes motor stalling. These findings highlight that the mechanical inertia of the drive system plays a critical role in maintaining motor stability during abnormal supply conditions. Finally, this article provides quantitative evidence on the combined influence of inertia and disturbance severity, offering valuable insight for the optimal design of protection schemes and motor selection criteria in industrial applications.

### Keywords

Power quality, ride through capability, motor drive, induction motor

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Submitted : July 24, 2025. Accepted : November 24, 2025. Published : December 24, 2025.

### INTRODUCTION

Power quality, such stability and reliability, is a factor that must be maintained in an electric power system. Therefore, it is important to provide power with a stable voltage and frequency in the electric power supply industry. However, it is almost impossible to avoid interference with the electric power system because several disturbances may occur in the electric power system, especially the distribution system. One of disturbance or fault is the short circuit. This kind of fault causes a voltage drop. That's why voltage drop has emerged as one of the most serious power quality problems in recent years [1].

In general, voltage drop is a sudden decrease in voltage amplitude and then returns to its initial level after a while. The voltage drop is usually caused by several conditions such as switching on the distribution system, energizing the transformer, rapidly changing loads, and the use of equipment that requires high currents when starting [2][3][4]. The voltage drop is an important power quality problem on the distribution side especially for industry with dynamics loads consisting many three phase electric motors.

As the voltage drop appears, the electrical load especially an induction motor is expected to keep running. This condition is known as ride-through capability. According to [5][6][7], ride through capability is the ability of the equipment being tested to survive in a state of voltage drop and momentary disturbance for a specified duration and magnitude without any malfunctions. In this case it is a point of view on the load side. In terms of power generation, ride through capability is the ability of the power supply to send power that can be used for a limited time during power loss [8][9][10]. Thus, a brief loss of power can cause sensitive electrical equipment to shut down, damaging circuits, and increase maintenance costs. Ride through capability is useful when there is a short power outage and when other disturbances occur.

Previous research discussing about ride through capability mostly describe the effort to overcome to voltage drop on the voltage source. In [11], a low voltage ride through control strategy is discussed on the susceptibility of grid-connected photovoltaic system against grid faults. The implements of the crowbar resistance protection scheme on wind farm for enhancing the low voltage ride through capability of wind turbine is described in [12]. In [13], the passive low voltage ride through capability method as well as the active low voltage ride through capability method were developed for the purpose of transient analysis of the doubly fed induction generator. In [14] shows the necessity for improvements of the brushless doubly-fed induction generator low voltage ride through capability with presenting a comprehensive analytical study during asymmetrical voltage dips. Enhancement of fault ride-through capability in doubly-fed induction generator system is presented in [15]. The performance of the ring-based saturated core fault current limiter is analyzed with the help of experimental setup. Accordingly, a research gap remains in quantifying the mechanical response of induction motors during voltage grid disturbances condition as the motor expected to be keep running, particularly from the perspective of the load-side dynamics. Unlike the studies in [11]–[15] which primarily focus on generation-side systems (e.g., DFIG or PV-based converters), the present work explicitly investigates the disturbance impact on induction motors as the downstream electrical load..

Therefore, this study aims to quantitatively analyze the influence of different types of voltage disturbances and variations in rotor moment of inertia on the speed profile and ride-through capability of a three-phase induction motor under three different starting approaches.

## METHOD

This section aims to illustrate the design of the simulation-based experiment for three phase induction motor testing and procedure followed to obtain the results on performance and parameter ride through capability of three phase induction motor.

*Table 1. Three phase induction motor parameters*

No	Parameters	Quantities and Units
1	Rs (stator)	0.294 $\Omega$
2	Ls (stator)	1.39mH
3	Rr (rotor)	0.156 $\Omega$

No	Parameters	Quantities and Units
4	Lr (rotor)	0.74mH
5	Lm (magnetizing)	41mH
6	Ns	1000 rpm
7	Pole	6

Table 1 shows the parameters of a three phase induction motor and Figure 1 shows the electrical configuration for the simulation using the PSIM software. A power source with a voltage of 380 V rms is used to supply a three phase induction motor. The motor is loaded by mechanical load constant torque with the value of torque is 20. Then the voltage grid disturbance scheme is used for generating voltage grid disturbance. This scheme is capable for producing any arbitrary waveform and nominal voltages for every phase. The induction motor starting method used in the simulation is conventional method. Voltage and speed measured by probe will be analyzed.

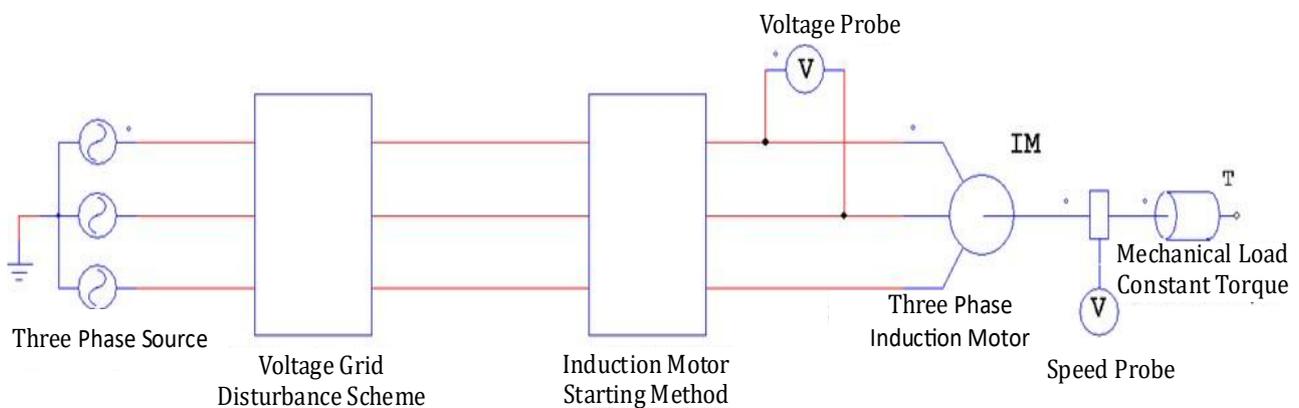


Figure 1. The electrical configuration for 3-phase induction motor

The simulation-based experimental can be grouped into three parts i.e., investigation of starting three phase induction motor with direct on line method (case 1), autotransformer method (case 2), and wye-delta method (case 3). These three starting methods are used because they are commonly used in real-world applications, so this simulation-based experiment is expected to be effective.

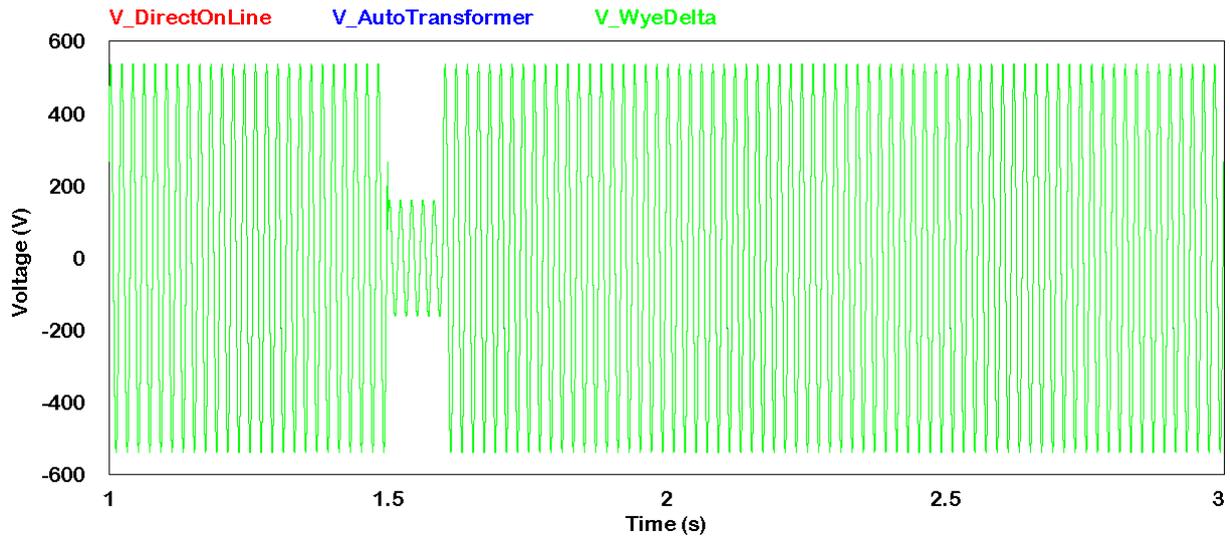
The works in each case are carried out with various types of voltage grid disturbance such as short duration sag, long duration sag, momentary swell, and momentary interruption. Short duration sag and long duration sag were set at 30% of the nominal voltage. Momentary swell was set at 130% of the nominal voltage. The duration of short duration sag is 0.1s or 5 cycles. The duration of long duration sag, momentary swell, and momentary interruption are 1s or 50 cycles. The works in each case are also carried out by varying the value of the moment of inertia on the induction motor with values of 0.4 and 0.8.

## RESULT AND DISCUSSION

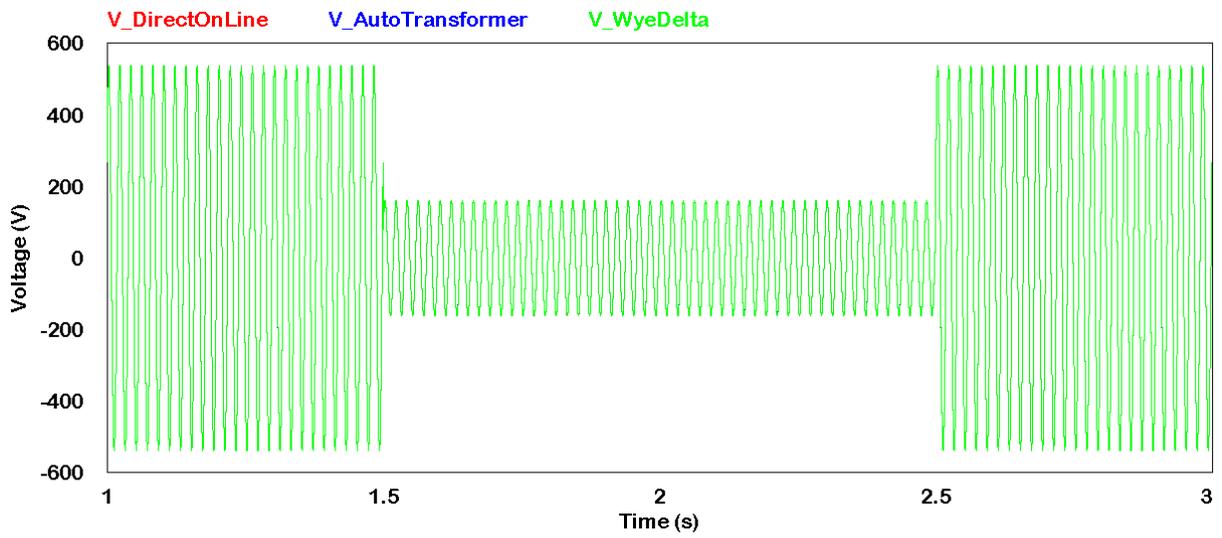
In order to get a clear and step-by-step idea about the performance and parameters affecting ride-through capability of three phase induction motor, the following test were carried out.

### Testing of The Voltage Grid Disturbance

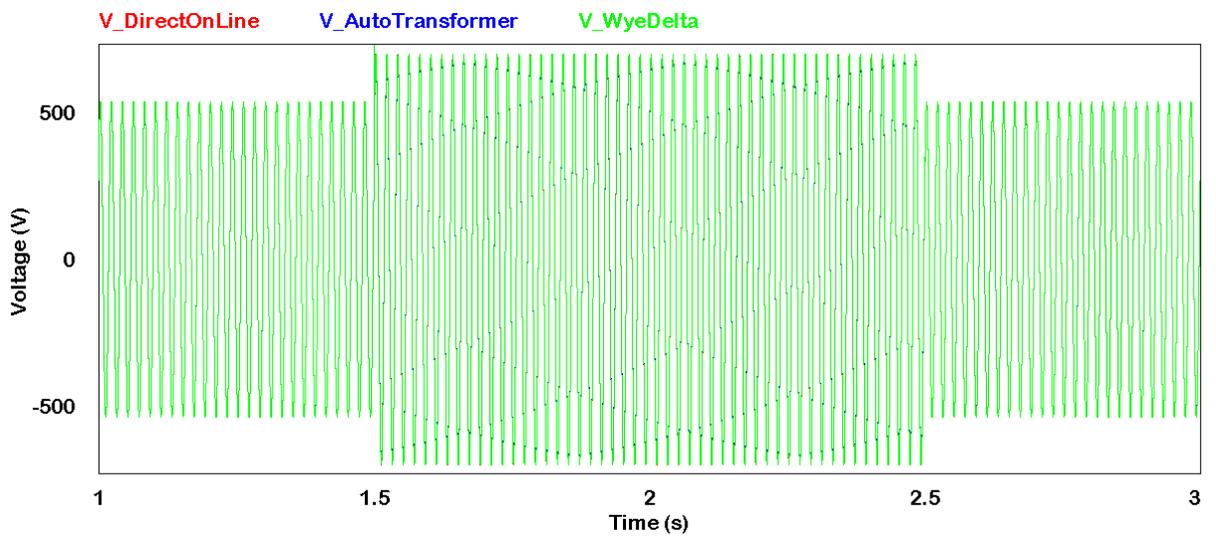
Figure 2 shows the wave profile of each voltage grid disturbance. From this figure, the voltage drops or rises suddenly to the preset voltage and then returns to its nominal voltage after a certain period of time.



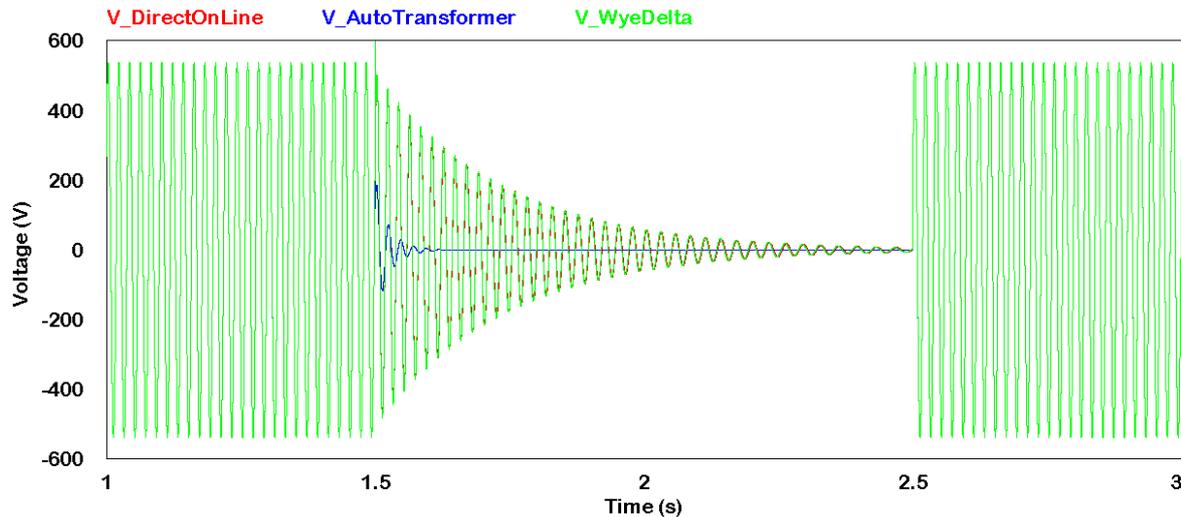
(a)



(b)



(c)



(d)

Figure 2. Voltage sag waveforms : (a)short duration sag ; (b)long duration sag ; (c)momentary swell ; (d) momentary interruption

### Influence of Various Types of Voltage Grid Disturbance and Moment of Inertia

This section shows the effect of various types of voltage grid disturbance and moment of inertia of the motor on the starting method of a three phase induction motor. A six poles squirrel cage induction motor is used. Then the speed profile will be listed to determine the performance and parameter of the three phase induction motor.

The effect of various types of grid disturbance on direct on line starting method with varying values of moment of inertia is shown in Figure 3. This figure shows a decrease in speed when the voltage grid disturbance is applied, especially for short duration voltage, long duration voltage and momentary interruption. But the speed is unstable for a few moments during the momentary swell. Motor speed will try to keep running during the voltage grid disturbance scheme. But the motor may stall during momentary interruption. This is because the value of the voltage during momentary interruption is zero voltage and the motor is loaded. After the voltage grid disturbance scheme is over, the motor will re-accelerate to its normal condition again. Motor speed reduction depends on the value of the moment of inertia of the motor. As shown in Fig. 3(a), for the moment of inertia value of 0.4, the long-duration voltage sag causes the motor speed to drop from 1000 rpm to approximately 820 rpm, corresponding to an 18% reduction. In contrast, Fig. 3(b) illustrates that with a higher moment of inertia of 0.8, the speed only decreases to around 900 rpm, representing a 10% reduction. The greater the moment of inertia, the lower the motor speed will decrease as shown in the figure.

Figure 4 shows the effect of various types of grid disturbance on autotransformer starting method with varying values of moment of inertia. The performance and conditions are the same as the direct on line method. The difference is only in the initial starting conditions. However, this is not a factor in various types of voltage grid disturbance. Therefore, the difference in the starting method is not a parameter that affects ride through capability on a 3-phase induction motor.

Figure 5 shows the effect of various types of grid disturbance on wye-delta starting method with varying values of moment of inertia. It was previously mentioned that the difference in the starting method is not a parameter that affects ride through capability on a 3-phase induction motor. However, there are differences in this method. This is because the construction and characteristics of the induction motor used are different from the previous 2

methods. This method uses a linear type induction motor for wye-delta starting purposes. Thus, the used of motor construction and characteristics can be a parameter of the ride through capability of a 3-phase induction motor.

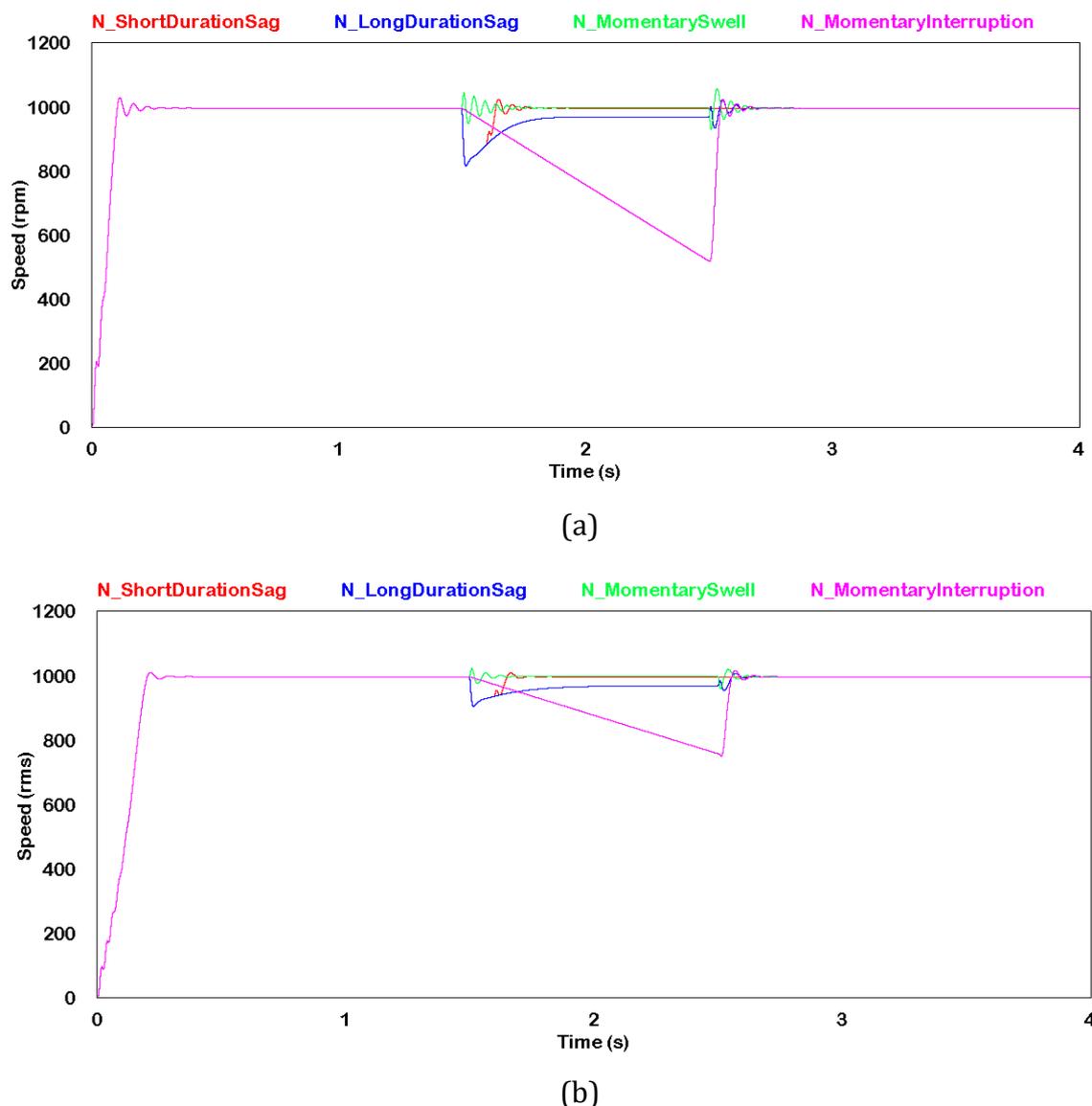
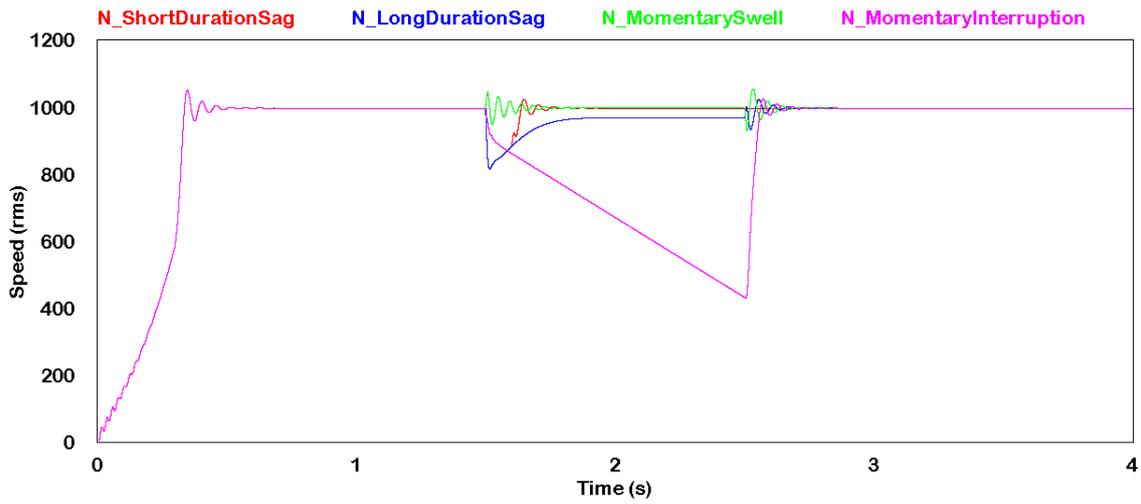
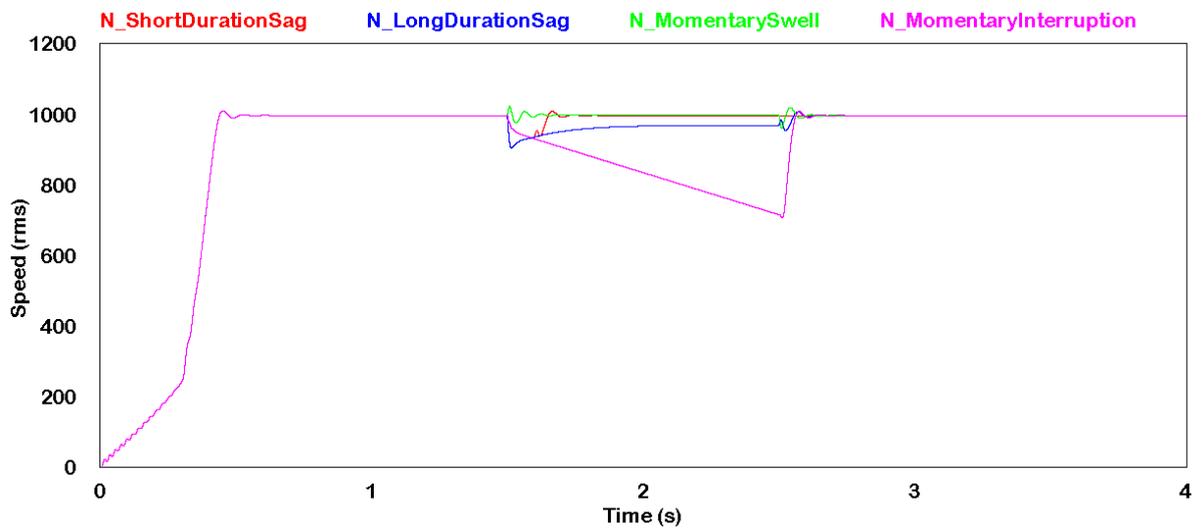


Figure 3. Speed waveforms of direct on line method : (a)moment of inertia 0.4 ; (b)moment of inertia 0.8

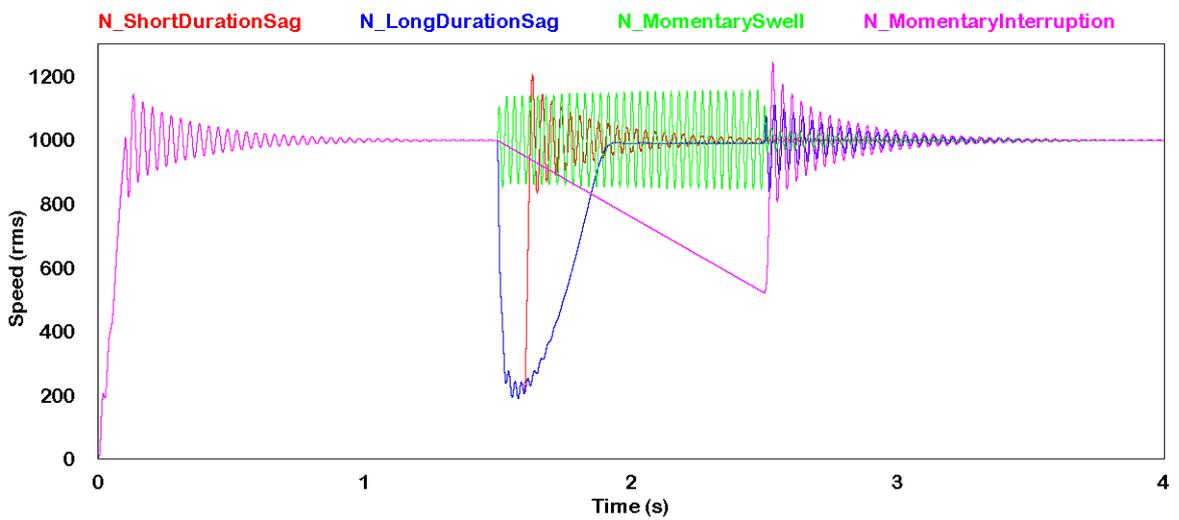


(a)



(b)

Figure 4. Speed waveforms of autotransformer method : (a)moment of inertia 0.4 ; (b)moment of inertia 0.8



(a)

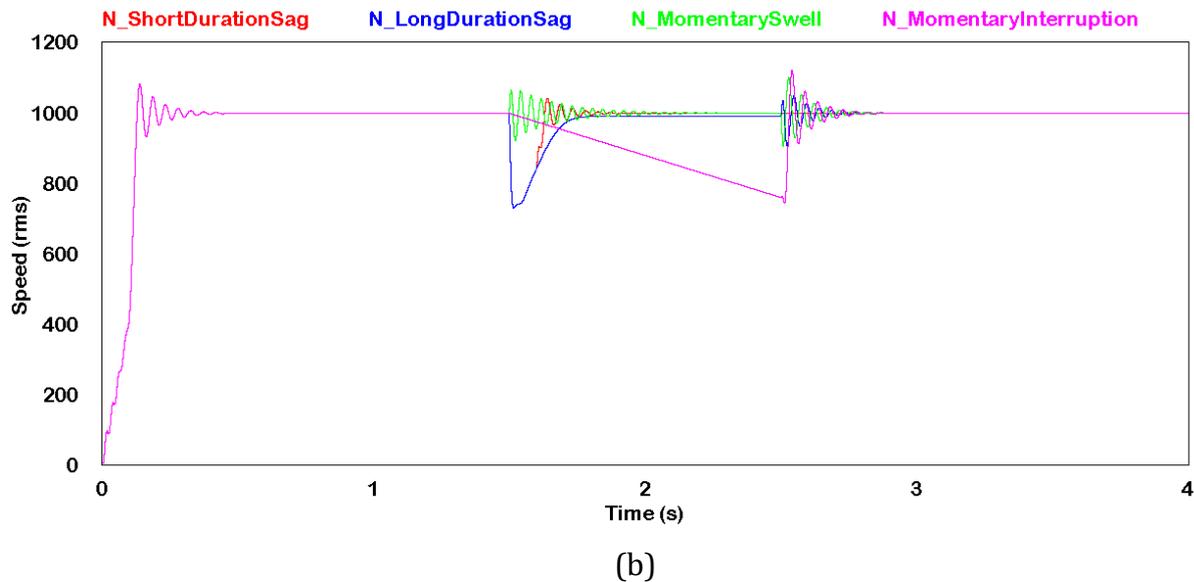


Figure 5. Speed waveforms of wye-delta method : (a)moment of inertia 0.4 ; (b)moment of inertia 0.8

### CONCLUSION AND FUTURE WORK

The performance and parameters affecting ride-through capability of three phase induction motor are obtained based on the simulation-based experimental results and analysis in this article. A simulation-based experimental has been carried out on various types of starting method which consist of direct on line, autotransformer, and wye-delta. Influence of various types of grid disturbance is not different for each starting method, but the motor may stall during momentary interruption. Influence of moment of inertia of the motor is significant. Influence of various types of starting method do not show any difference, but for the wye-delta method shows the difference. This is because influence of specifications of the induction motor. From a practical standpoint, these findings imply that, for critical industrial applications, the total moment of inertia (motor and load) should be treated as a key design parameter in motor selection, as it directly governs the mechanical ride-through capability under voltage disturbance conditions.

The hypothesis said that moment of inertia is significant has been confirmed through the simulation-based experimental. The results of simulation show that the greater the moment of inertia, the lower the motor speed will decrease. When the moment of inertia is large enough, the motor will keep running during the voltage grid disturbance condition even though the voltage drop is very extreme.

Based on PSIM simulation result, future research may be directed toward experimental validation using hardware-in-the-loop or laboratory-scale prototypes, as well as investigating the impact of harmonic distortion on motor ride-through capability, or developing enhancement strategies to further improve ride-through performance.

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