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Simulation Model for Analysis the Induction Motor Starting Methods in Term of Electrical Power Quality

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Abstract— Power quality is one of the most talked about topics these days. Both the power utilities and customers are quite concerned with the quality of the power supply, whether it is the power generated by the power utilities or the power consumed by the customers respectively. The most frequent power quality events that occur are voltage sags and voltage transients as well as harmonics. Generally, voltage sags occur due to short-circuit faults, however, motor starting is also the main cause of the voltage sags. Induction Motor draws a high starting current during starting period which effects on electromagnetic torque, speed and current. Traditional method include induction motor direct on-line, auto transformer, star delta starter etc. This paper presents a comparison between the Direct-On-Line and Star-Delta induction motor starting method in terms of power quality. Simulation is made in MATLAB and comparatively results are estimated. The analysis of induction motors operation under voltage sags is investigated.

Index Terms— Power quality, induction motor, voltage sags, starting methods.

1 Introduction

Power quality is a new whole area within electrical engineering where fundamental research involves basic concept and definitions; modeling and analysis; measurement and instrumentation; sources; effect; and mitigation. The ultimate goal of power quality research is to maintain a satisfactory quality of electric supply. Power quality disturbances such as under-voltage (sag), over-voltage (swell), surges and harmonics have been identified as the major sources of power quality problems. The most common power quality problem in industrial distribution systems are the voltage disturbances, which mainly encompasses the voltage sags, swells, harmonics, transients, unbalances, and flickers. These disturbances can cause the malfunction of voltage-sensitive loads in factories and buildings. However, the outcome of many power quality surveys was concluded that more than 90% of voltage related events are the voltage sags. [1-4].

The dynamic nature of induction machines means that they draw current depending on the mode of operation; during starting this current can be as high as six times the normal rated current. This increased loading on the local network has the effect of causing voltage sag, the magnitude of which is dependent on the system impedance. It can take several seconds for motors to reach their rated speed and for this reason measures are taken to reduce the level of current drawn [5].

Voltage sag is normally caused by short-circuit faults, such as a single-line to-ground fault in a power system and by the start-up of motors of large ratings, causing enormous financial production losses. This paper will focus on the effects of voltage sag during starting of an induction motor. The aim of this research is to compare the outcomes the best method of starting of an induction motor using different starting methods, and find out the voltage sag during starting the motor.

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2 Power Quality Events in Induction Motor Starting

Voltage sags are short-duration reductions in rms voltage caused by short- duration increases of the current, typically at another location than where the voltage sag is measured. The most common causes of over currents leading to voltage sags are motor starting, transformer energizing and faults. Also capacitor energizing and switching of electronic load lead to short duration over currents, but the duration of the over current is too short to cause a significant reduction in the rms voltage. These events are normally not referred to as voltage sags but as voltage notches or voltage transients. Voltage sags due to short circuit and earth faults are the cause of the vast majority of equipment problems. Most of the recent emphasis on voltage sags is directed towards these fault-related sags. Voltage sags are generally seen as undesired events, but a more positive viewpoint could equally well see them as a consequence of the high reliability of the power supply [6].

Voltage sags may occur in starting motors due to the inrush current. This inrush current occurs because the motor draws six to ten times of current than usual to produce a starting torque. Voltage sags due to the starting of large motors can again be theoretically calculated similar to that caused by system faults [7-8].

$$v_{sag} = \frac{Z_m}{Z_s + z_m} E \tag{1}$$

Where Z_m is the impedance of the motor under study and Z_S is the source impedance as shown in Fig. 1.

These calculations provide approximations and an accurate

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result of voltage sag phenomena so a power system analysis package was used. Motor starting causes high inrush currents. In understanding of high inrush current due to the motor starting is necessary required because the power quality events may spoil the motor or affect the sensitive load at its surrounding.

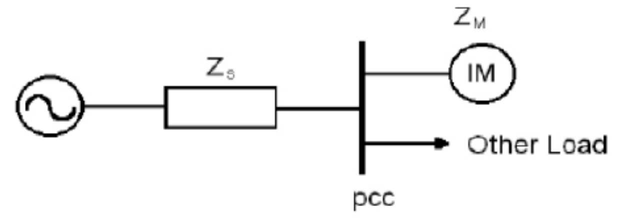

Fig. 1. Equivalent circuit for induction motor starting

3 SIMULATION RESULTS OF POWER QUALITY DISTURBANCE FOR INDUCTION MOTOR STARTING

The induction motor starting model is used to simulate voltage sag caused by starting a high power industry induction motor. The induction motor starting model developed in Simulink is shown in Fig. 2 [9]. The induction motor starting model can be used to simulate voltage sag caused by induction motor starting, the model consists of

- 11 kV, 30 MVA, 50 Hz three-phase source
- Feeder block feeding through 11 kV/0.4 kV
- 1 MVA Δ/Y transformers
- Three phase breaker as motor starting contactor
- Three-phase induction motor
- 10 kW resistive load

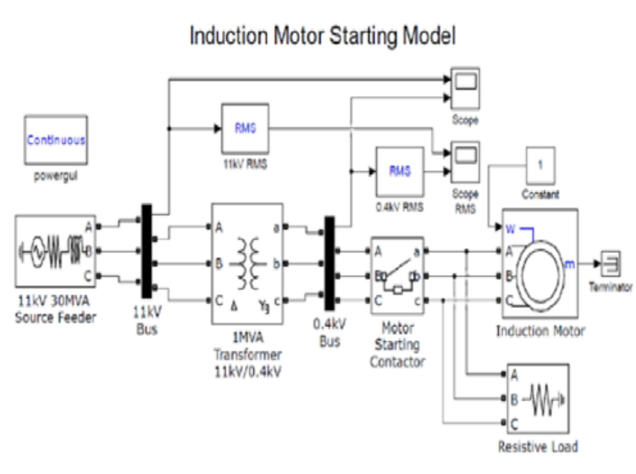

Fig. 2. Induction motor starting Simulink model

A. Direct-on-line start

Fig. 3 shows a three-phase voltage sag instantaneous waveform caused by a 150HP (1487 RPM) induction motor starting. The voltage sag pattern can be visualized clearly in RMS waveform as shown in Fig. 4. A higher induction motor power rating leads to a lower sag magnitude as shown in Fig. 5 and Fig. 6 for 100HP (75kW) induction motor starting .

It is clear the voltage sag can only be noticed at 0.4 kV bus waveform, furthermore three-phase induction motor starting voltage sag is typically balanced and has a shallow drop up to 15% from its nominal magnitude.The sag magnitude of the induction motor voltage sag is dependent on the induction motor power rating.

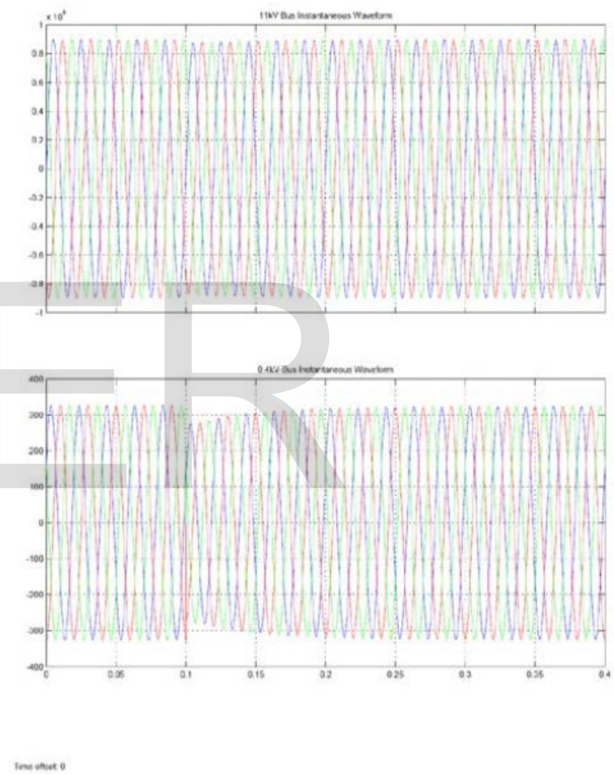

Fig. 3. Voltage sag instantaneous

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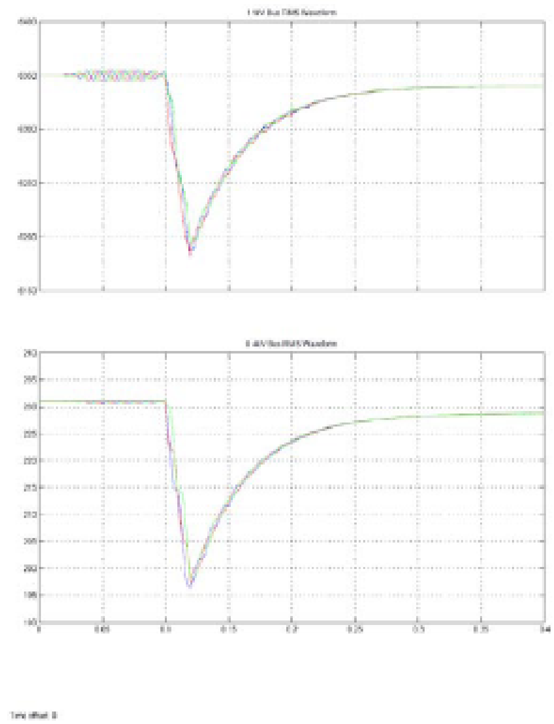

Fig. 4. Voltage sag instantaneous

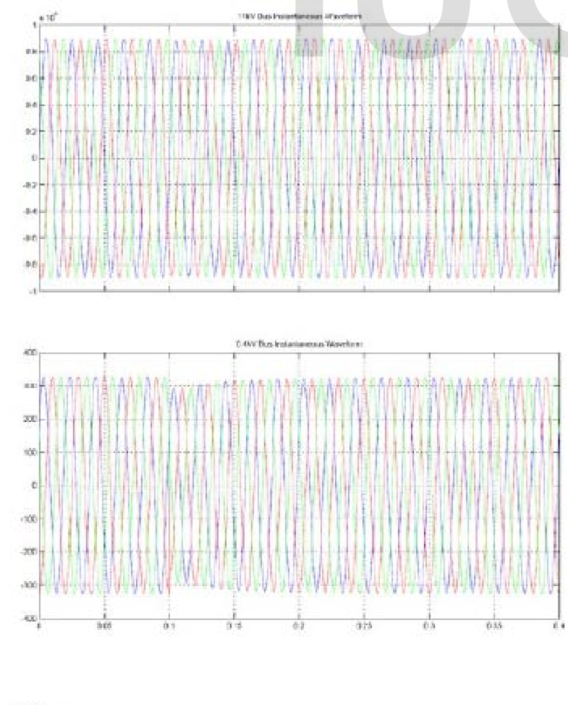

Fig. 5. Voltage sag instantaneous

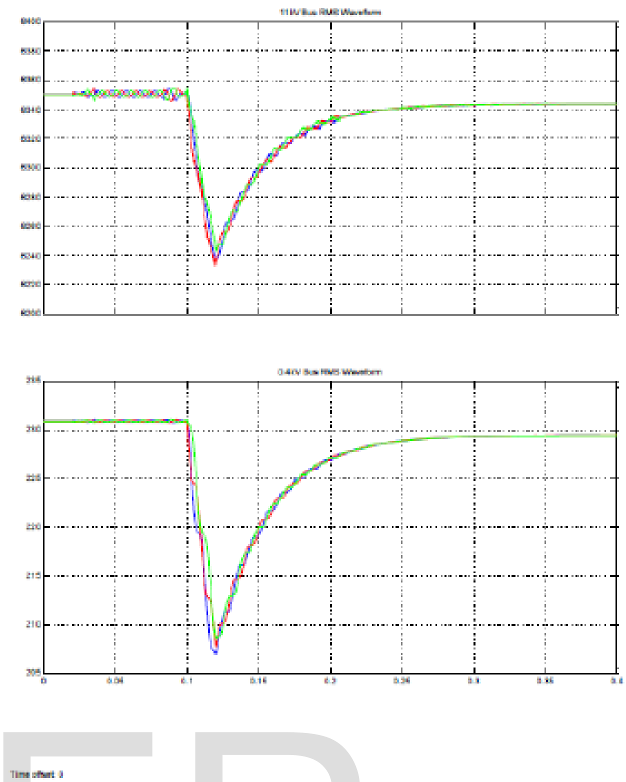

Fig. 6. Voltage sag instantaneous

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B. Star-delta start

Star/Delta starters are probably the most common reduced voltage starters. They are used in an attempt to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply.

The simulink model of star-delta starting is achieved by physically reconfiguring the induction motor starting simulink model in Fig. 2. There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. The third contactor is the star contactor and that only carries star current while the motor is connected in star.

Fig. 7 shows a three-phase voltage sag instantaneous waveform caused by a 150HP (110 kW) induction motor starting. The voltage sag pattern can be visualized clearly in RMS waveform as shown in Fig. 8. Fig. 9 and Fig. 10 show a three-phase voltage sag instantaneous waveform and RMS waveform caused by a 100HP (75kW) induction motor starting.

It is clear the voltage sag in the Star-Delta starting occurs during the transition from the Star connection to the Delta connection. During the transition moment, the contactor switches and causes the voltage to breakdown for an approximately of 0.1 seconds and this is enough to cause the voltage sag to occur in the motor starting.

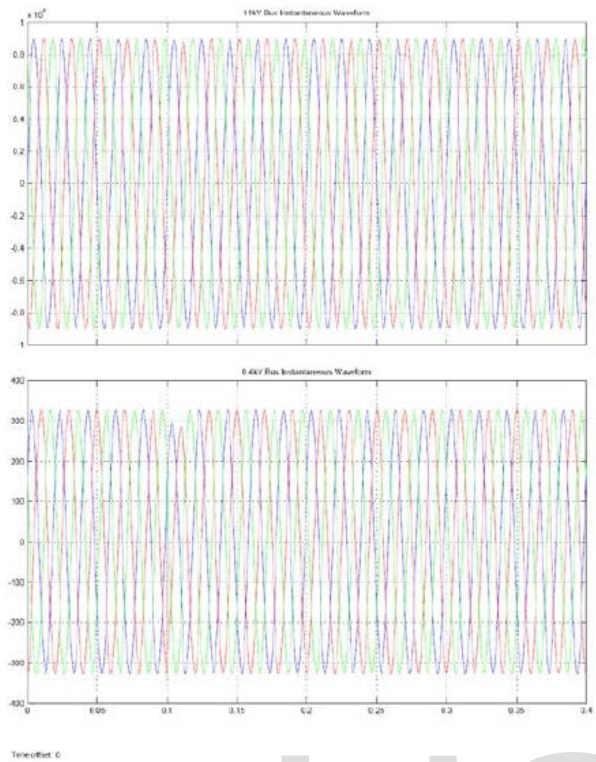

Fig. 7. Voltage sag instantaneous

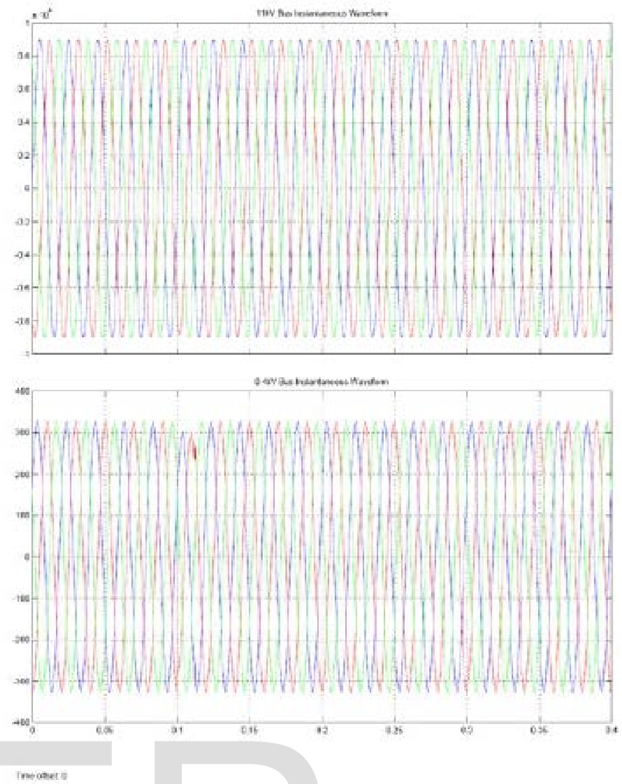

Fig. 9. Voltage sag instantaneous

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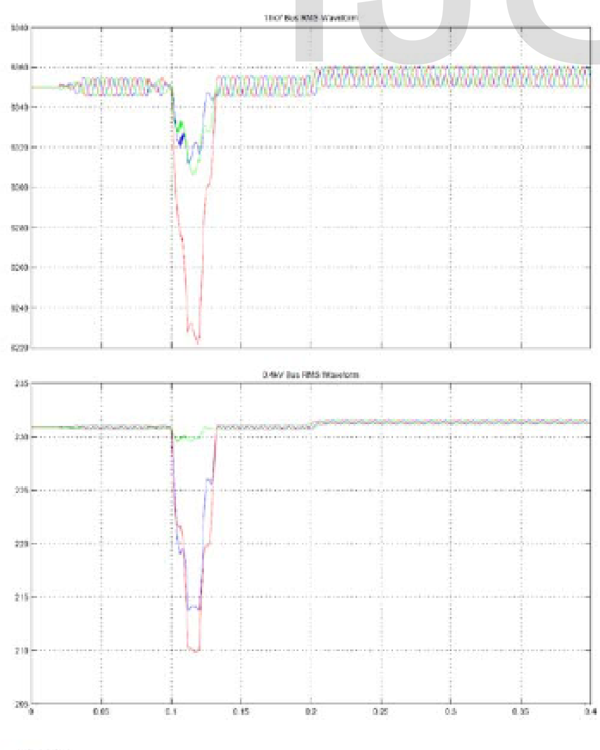

Fig. 8. Voltage sag instantaneous

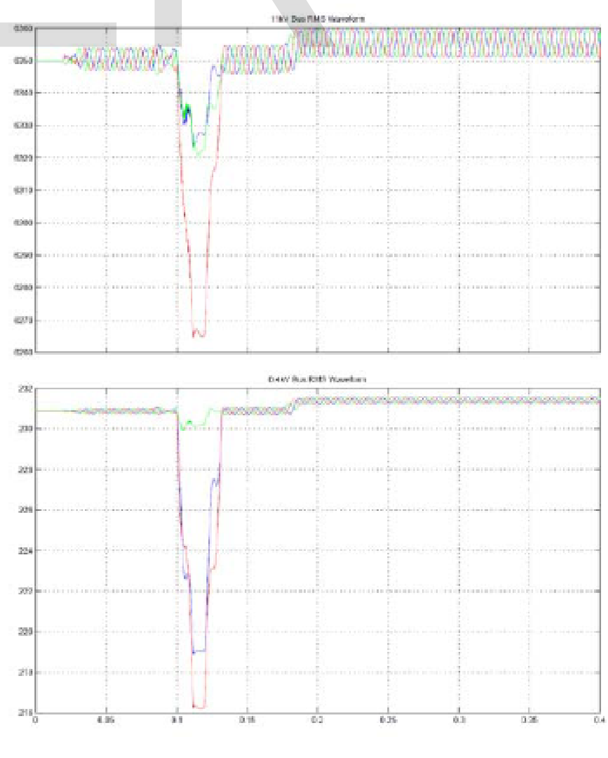

Fig. 10. Voltage sag instantaneous

4 Conclusion

This paper presented efficient methods for power quality data analysis on motor starting circuits. Behavior of induction motor with different sizes due to voltage sags can be studied using MATLAB/ Simulink. Results illustrate the Direct-On-Line starting method yields the least power quality problem compared with Star-Delta starting motors. This comparison is valid for the low power rated motor; however, in the higher output power rating motors, this comparison may not be suitable. Future work suggests the proposed tools to mitigate the voltage sag due to Direct-On-Line starting of three phase induction motors.

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