INDUCTION MOTOR STARTING IN A POWER SYSTEM USING EDSA PALADIN DESIGNBASE SOFTWARE

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Abstract **This paper presents a study using EDSA Paladin DesignBase (EDSA Technical 2005) to investigate different motor starting procedures. Main system characteristics for each method are introduced and then simulated using the Advanced Motor Starting program. Current and torque variation versus time are calculated for every method studied according to the program.**

1. INTRODUCTION

The starting current of most AC motors is several times larger than the full load current. At start-up, values up to four to eight times full load current can be reached. Also, the motor starting torque is directly dependent with the square value of the applied voltage. If the voltage is too low, there is the possibility for the motor not to operate. If the motors are started frequently, problems may appear, causing flicker in the lightning system, and not only.

By using motor starting study procedures, one can see the problems that may arise in the system. This gives engineers the possibility to choose the best method for starting an induction motor, to properly design a motor, or to minimize the impact of motor starting on the entire network.

There are several starting methods which differ according to the motor and load specifications. The methods that are outlined in this paper are:

- Direct-on-line starting
- Auto-Transformer starting
- Star-Delta Connection
- Solid State Voltage Control

All calculations were performed using EDSA Paladin Design Base software. The method used by the program is from IEEE Brown Book for motor starting. The motor starting solution is an accurate and fast method of assessing motor starting conditions, without resorting to a time domain simulation program.

In order to perform a motor starting study within the EDSA Paladin DesignBase software, the following data are required:

- Motor impedances and ratings,
- Motor and load moment of inertia,
- Motor load characteristics,
- Motor starting method.

The program carries on a series of power flows to determine motor performance as a function of time during the motor's starting period. At each iteration, the motor's swing equation (equation of rotation) is solved to obtain the motor's speed. The results of the motor starting analysis are time based tabulation of motor current, motor terminal voltage, motor torque, power and power factor.

2. CASE STUDY NETWORK

Simulation studies were conducted using the Advanced Motor Starting program from EDSA Paladin DesignBase. The simulated system, shown in Fig. 1, is supplied from a 20 kV power grid. The network has two transformers, T1 and T2, 20/6 kV. The induction motors, M1 to M4 are connected to the transformers through a bus bar, BUS2. As protection devices, circuit breakers have been used. The induction motor that will be used for simulating different motor starting methods is M1. Its nameplate parameters are presented in Table 1.

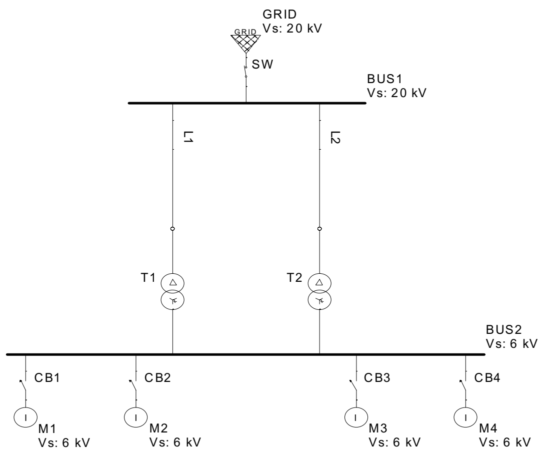

Figure 1: Case study network

Motor Rated Power (kW)	2000
Motor Synchronous Speed (rpm)	1500
Motor Rated Speed (rpm)	1490
Motor Rated Efficiency (%)	96.8
Motor Rated Power Factor (%)	90
Current Start Factor	6
Torque Start Factor	0.8
Motor Moment of Inertia (kg m^2)	96

Table 1: Motor's parameters

Based on these data, simulations have been performed for different motor starting techniques. Graphic and text results are presented for current, torque and voltage characteristics.

3. DIRECT ON LINE STARTING

Direct-on-line starting is the most common starting method available. In this case the induction motor is directly connected to the power system. The major problem that arises when using this method is that it gives the highest possible starting current. This value can be four to eight times the full load current value. The high current is the main cause why this method can be used only for starting induction motors with small rated powers or motors that are not affected by the shock of starting.
Simulations have been performed based on the network shown in Fig. 1. First, induction motor M1 was set to start at full voltage, with a load torque of 20% from the rated torque. Results for current and torque characteristics as a function of time obtained from Advanced Motor Starting are presented in Fig. 2 and Fig. 3.

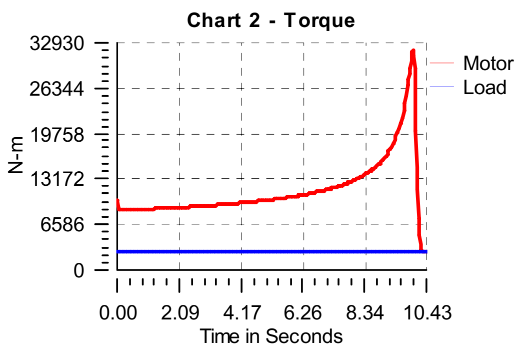

Figure: 2 Torque vs time for Direct-on-line starting

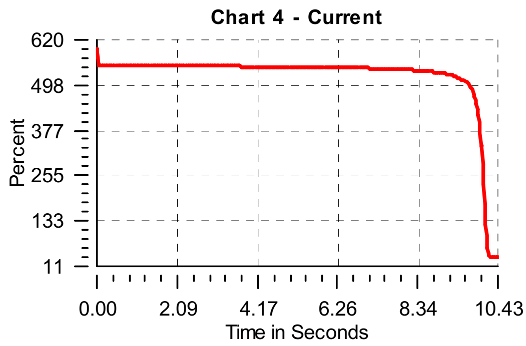

Figure 3: Current vs time for Direct-on-line starting

The results for current obtained from the program appear in percent of the rated current.
Accelerating time, maximum current and torque values are presented in Table 2.

Accelerating time (s)	8.38
Total accelerating time (s)	10.43
Maximum torque (%)	248.43
Maximum current (%)	595.90

Table 2: Text results for direct-on-line starting

4. WYE DELTA STARTING

Wye-delta starting is a motor starting method used for reducing the starting current and starting torque. In this method the starting and the starting torque are reduced to a third part of their rated values.
This method can only be used for induction motors that are normally delta connected during normal run and are not too heavily loaded.
For this case, we set the induction motor M1 to switch from wye connection to delta connection after 56 seconds. The load torque was set to 20% from the nominal torque. Results for current and torque characteristics as a function of time obtained from Advanced Motor Starting are presented in Fig. 4 and Fig. 5.

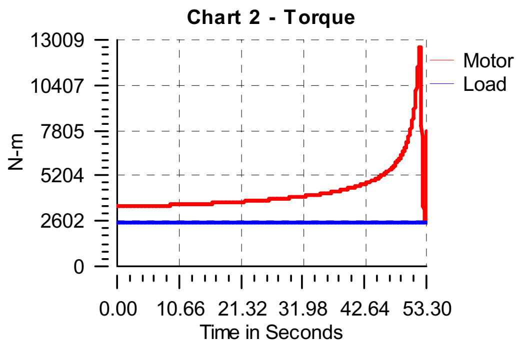

Figure 4: Torque vs time for wye-delta starting

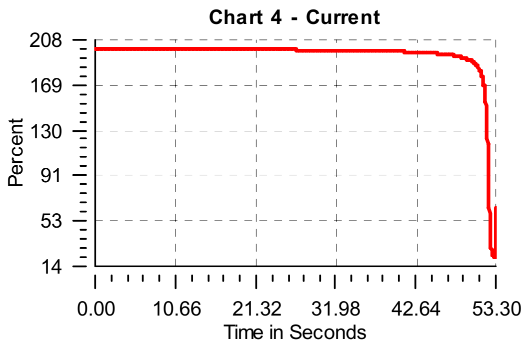

Figure 5: Current vs time for wye-delta starting

The results for current obtained from the program appear in percent of the rated current.
Accelerating time, maximum current and torque values are presented in Table 3.

Accelerating time (s)	53.22
Total accelerating time (s)	53.30
Maximum torque (%)	98.14
Maximum current (%)	200

Table 3: Text results for wye-delta starting

5. AUTOTRANSFORMER STARTING

Another method used for motor starting is by using an autotransformer. This way, the applied voltage is reduced until the autotransformer is switched off. The autotransformers used for motor starting are generally equipped with taps for adapting the motor start characteristics to the torque requirement. These taps are usually set to 80%, 65% or 50%.
For this case, the autotransformer's tap is set at 50%. The autotransformer is switched off at 73 seconds. The load torque was set to 15% from the nominal torque.

Results for current and torque characteristics as a function of time obtained from Advanced Motor Starting are presented in Fig. 6 and Fig. 7.

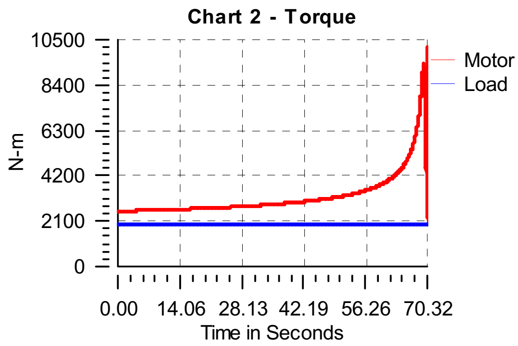

Figure 6: Torque vs time for autotransformer starting

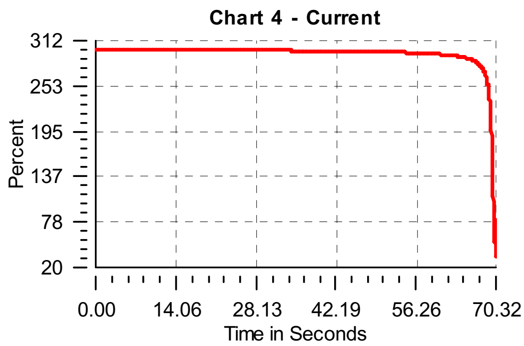

Figure 7: Current vs time for autotransformer starting

The results for current obtained from the program appear in percent of the rated current.
Accelerating time, maximum current and torque values are presented in Table 4.

Accelerating time (s)	70.25
Total accelerating time (s)	70.32
Maximum torque (%)	79.22
Maximum current (%)	299

Table 4: Text results for autotransformer starting

. VOLTAGE CONTROL

Development of electronic circuits in the past years has been an advantage for motor starting techniques. Electronic devices can be used in order to control the motor voltage when it is started. By applying a low voltage during start-up, the starting current and starting torque will also be low. Using this method, the voltage varies continuously or in discrete steps.

In EDSA Paladin DesignBase we were able to simulate motor starting using Solid State Voltage Control. The time-tap characteristics for this method are presented in Table 5. The induction motor is switched to full voltage after 46 seconds. The load torque was set to 20% from the nominal torque.

Time (s)	Tap (%)
0	60
43	70
44	80
45	90
46	100

Table 5: Text results for solid state voltage control

Results for current and torque characteristics as a function of time obtained from Advanced Motor Starting are presented in Fig. 8 and Fig. 9.

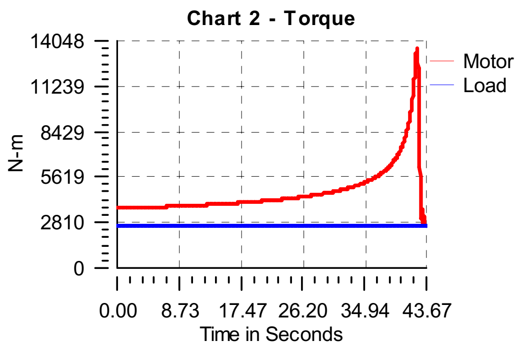

Figure 11: Torque vs time for solid state voltage control

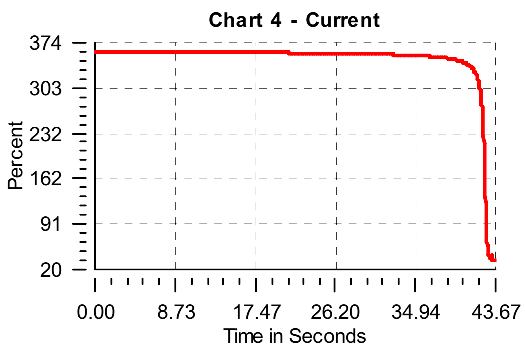

Figure 12: Current vs time for solid state voltage control

The results for current obtained from the program appear in percent of the rated current.

Accelerating time, maximum current and torque values are presented in Table 6.

Accelerating time (s)	43.47
Total accelerating time (s)	43.67
Maximum torque (%)	105.99
Maximum current (%)	359.8

Table 6: Text results for solid state voltage control

. CONCLUSIONS

Different motor starting methods have been outlined based on the system proposed. Simulations have been performed using Advanced Motor Starting program from EDSA Paladin DesignBase software. Torque and current characteristics have been outlined for each starting method. Graphic as well as text results have been presented. If the motor is used in a system that has to start a load very quickly, and the inrush current is not so important, the best choice for motor starting is using full voltage. However, if the load is sensitive, and the inrush current can not exceed a certain value, the user should choose one of the following methods: wye-delta starting, autotransformer starting or solid state voltage control.

The results obtained from the program can be used to observe the effect of voltage dip experienced through an industrial power system as a result of starting large motors, to conduct a detailed speed-torque analysis, accelerating time studies, and to coordinate properly the protection devices.

Acknowledgments

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