Sensorless Fuzzy Logic Soft Start of Induction Motor With Load Detection

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Abstract: In recent years, fuzzy logic has received greater emphasis in the field of power electronics and motion control by virtue of its adaptive capability. A new fuzzy logic based soft-start scheme for induction motor drives close to load detection has been discussed here using microcontroller based thyristorised voltage controller. Rule based soft-start algorithm is fully realised through a software approach only. The soft-start strategy is based on the change of input impedance during starting period. The prototype has been tested under various loading conditions and found to be reliable.

Keywords: Fuzzy Logic, Induction Motor, Soft Start, Load Detection

1. INTRODUCTION

It is estimated that more than 50% of the world electric energy generated is consumed by electric machines [1].

There are different methods for the starting of induction motors including direct on-line starting, star-delta starting etc. However the method of starting used nowadays is the Soft-start. These Soft-starts use an AC voltage controller to control the stator voltage supplied to the induction motor. Soft-starters increase voltage across the motor so that the rated voltage will appear across the motor at the end of soft-starting. Previously the stator voltage supplied was gradually increased by merely varying the firing angle at which the thyristors of the AC voltage controller were triggered [2]. Later certain parameters like current, voltage across the (non-conduction) thyristor and Icos? were monitored to sense the end of soft-start or any irregularities which starting [3, 4, 5].

In this paper a different parameter viz. input impedance of the motor for load detection and adjust starting time has been used.

2. Induction Motor (IM) Soft-starting

One traditional way of simulating on IM drive is to use an equivalent circuit model for IM. However, this is not the best approach when it is needed to study the performance of the drive during transient. The best approach is to describe the IM model through differential equation in d-q model. However, when it is needed to simulate the IM drive with switching networks (like ac voltage controller), it is not wise enough to describe the whole drive system through equations for various modes of operation. It is better if the switched network is represented as a circuit. Also, when it is needed to simulate a large system, it is better to follow a modular approach while modeling the whole system. The use of modularity in modeling offers many advantages such as the following :

1) ease of partitioning of the design tasks
2) ease of reuse in other designs
3) ease of debugging where ever there is a problem in the subsystem

Hence, the modeling of the whole drive system is done in MATLAB language of SIMULINK simulator to conform to modular approach. This block diagram of whole drive system is shown in Fig3. Mechanical load on the shaft is DC generator that is given by : T_l ? k? where ? is the speed in rad/s. The value of k is so chosen that at rated speed a load of 15 N-m is applied to the motor. This load is full load. In the soft starting applied voltage to the IM is increased from zero

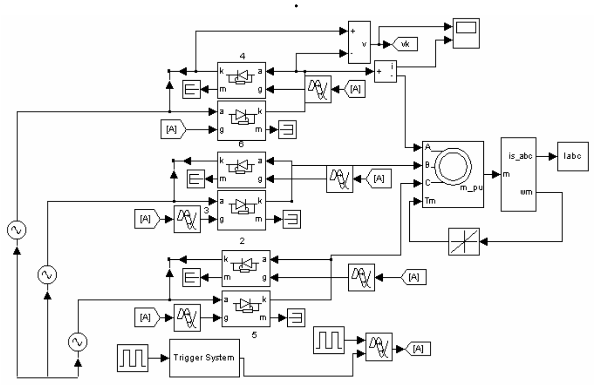

Fig 1: Voltage Controlled Induction Motor Drive

to rated voltage. But the load of IM is T_l ? k? when speed is low or beginning of soft starting, torque is so low therefore did not detect the IM load but after many simulation is shown the input impedance of IM during soft starting is changed then it is good parameter for load IM detection that the load is T_l ? k? .

3. Suggestion algorithm for load detection

The design procedure of novel soft starts is based on input impedance. This parameter is set manually with the help of DIP switches, quit approximately without knowing the dynamic of the system. Sometimes it is set by trial and observation method as well. In the fuzzy logic soft start scheme this parameter viz. Z_{in} is set by the controller itself depending on the dynamic of the system in terms of a set of fuzzy rules. $?_{max}$ is decided by load. In the universe of discourse there are six subsets for firing angle and input impedance. The number of subsets depends upon the number of fuzzy rules required to drive the required parameter. What more the number of subsets in the independent parameters certainly improve the accuracy of the fuzzy system. The linguistic terms used for membership functions for input impedance are : NL (No Load), VLL (Very Light Load), LL (Light Load), ML (Medium Load), SML (Semi Medium Load), FL (Full Load), and for variation of firing angle are : Z (Zero), VS (Very Small), S (Small), M (Medium), B (Big) and VB (Very Big). The membership function of input impedance is shown in Fig 2 and membership function of firing angle is shown in Fig 3. IM Input impedance is input of fuzzy controller and firing angle is output of fuzzy controller.

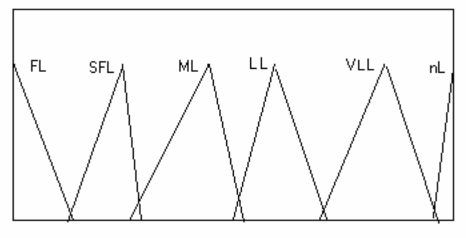

Fig 2: Input Impedance Membership Function

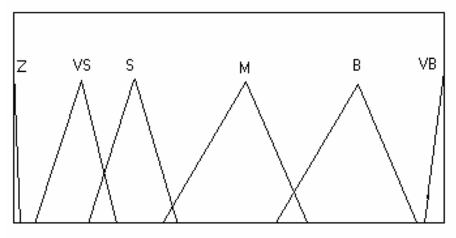

Fig 3: Firing Angle Membership Function

Relations (1-6) shows fuzzy controller rules. To start with an experimental test is performed by firing the thyristors at test ? (116^{o}). This is required to get value of $?_{max}$.

if Z =FL then ? ? = VB (1)

if Z =SFL then ? ? = B (2)

if Z =ML then ? ? = M (3)

if Z =HL then ? ? = S (4)

if Z =VHL then ? ? =VS (5)

if Z = nL then ? ? =Z (6)

The test procedure is as follows : Initially thyristors are fired at test $?_{max}$ =116 ^{o} then after 8 cycle input impedance (Z_{in} ? $\frac{V_{in}}{I}$) is read with ADC and based on it firing angle is evaluated. This algorithm is very simple and compatible for any microcontrollers. The suggestion algorithm is used for any load like DC generator.

4. Implementation of IM Soft-starting

Fuzzy logic based soft-start is tested on a three phase 2.2kw , 380V, 5.25A, 50 Hz ,squirrel cage induction motor for different loading condition (with a DC generator type of loading arrangement) as shown in Figs.4-11. Simulation Figs. are from up to down stator current rms (I_A), Line-Line stator voltage rms (V_{AB}), speed and Torque and experimental Figs are from up to down stator current rms (I_A),), Line-Line stator voltage rms (V_{AB}), speed. Fig.4,6 shows simulation result no load and 88% full load IM soft starting for 2.5 second (adjust time) and Fig.5,7 shows experimental result no load and 88% full load IM soft starting for 2.5 second (adjust time). The stator current rms is always under 2 Per Unit (PU) during starting and the start ing time for them is constant that's mean the driver has detected load and it adjust the variation of firing angle. The starting time is fixed 5 second For different starting time and loading condition. Fig.8,10 shows simulation result no load and 88% full load IM soft starting for 5 second (adjust time) and Fig.9,11 shows experimental result no load and 88% full load IM soft starting for 5 second (adjust time). The stator current rms is always under 2 PU during soft stating.

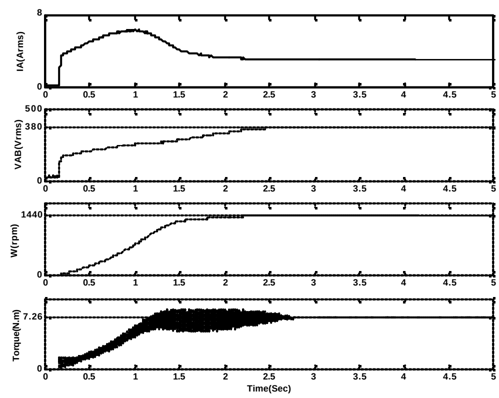

Fig 4: Simulation waveforms for fuzzy logic based soft start with no load and 2.5 Second starting time.

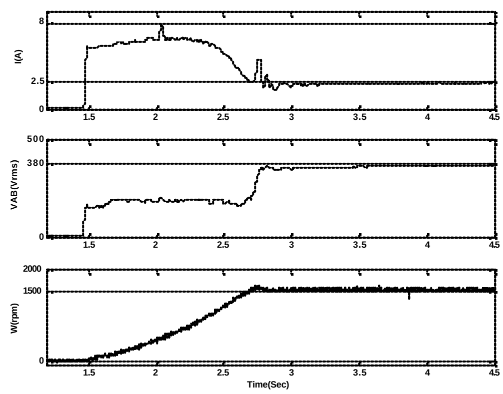

Fig 5: Experimental waveforms for fuzzy logic based soft start with no load 2.5 Second starting time

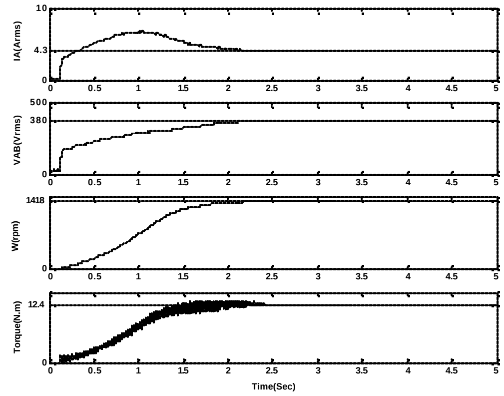

Fig 6: Simulation waveforms for fuzzy logic based soft start with 88% full load 2.5 Second starting time

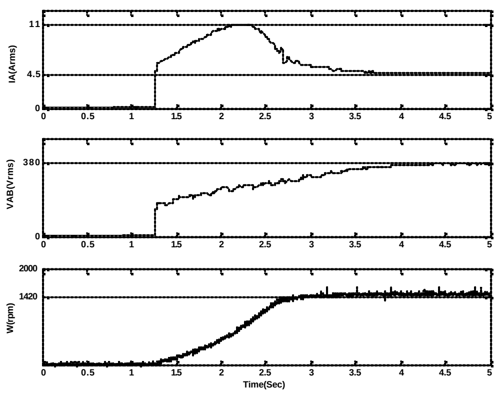

Fig 7: Experimental waveforms for fuzzy logic based soft start with 88% full load 2.5 Second starting time

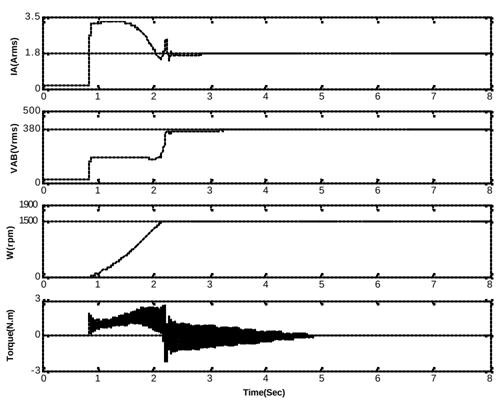

Fig 8: Simulation waveforms for fuzzy logic based soft start with no load 5 Second starting time

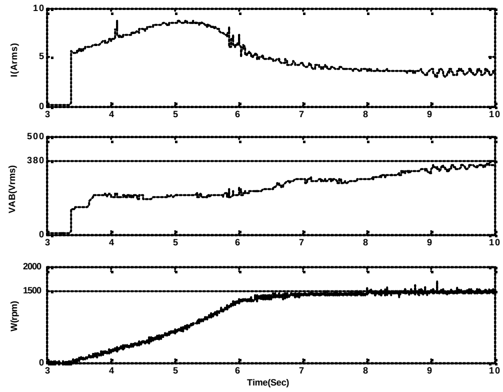

Fig 9: Experimental waveforms for fuzzy logic based soft start with no load 5 Second starting time

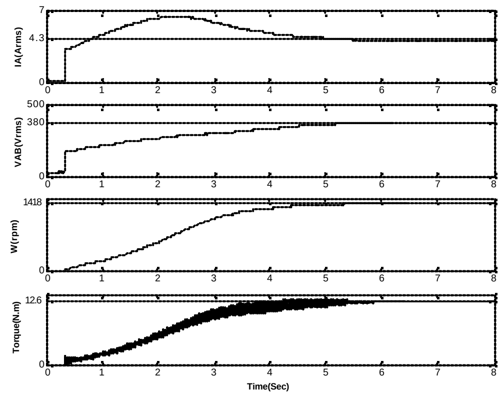

Fig 10: Simulation waveforms for fuzzy logic based soft start with 88% full load 5 Second starting time

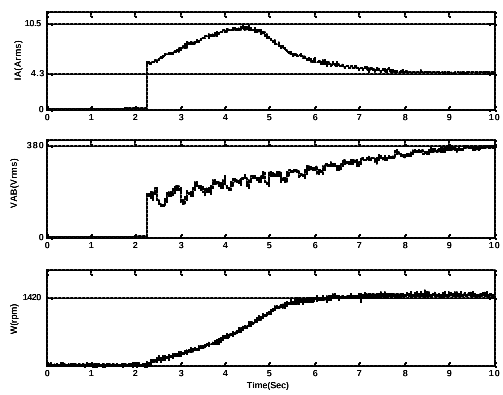

Fig 11: Experimental waveforms for fuzzy logic based soft start with 88% full load 5 Second starting time

5. Conclusions

This paper presents a novel fuzzy logic soft-start scheme based on input impedance measurement. This scheme is superior over other schemes since it has on-line adaptive parameter setting capability and also the ability to start any motor at any load, without any dip switches. Experimental results are presented to validate the above concept and They shows soft-starter has detected load and has adjusted firing angle according the load for adjusted starting time. The fuzzy based soft-start for induction motor drives does not call for a commissioning engineer.

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