# *Intelligent management and control of electrical loads using microcontroller-based embedded systems*

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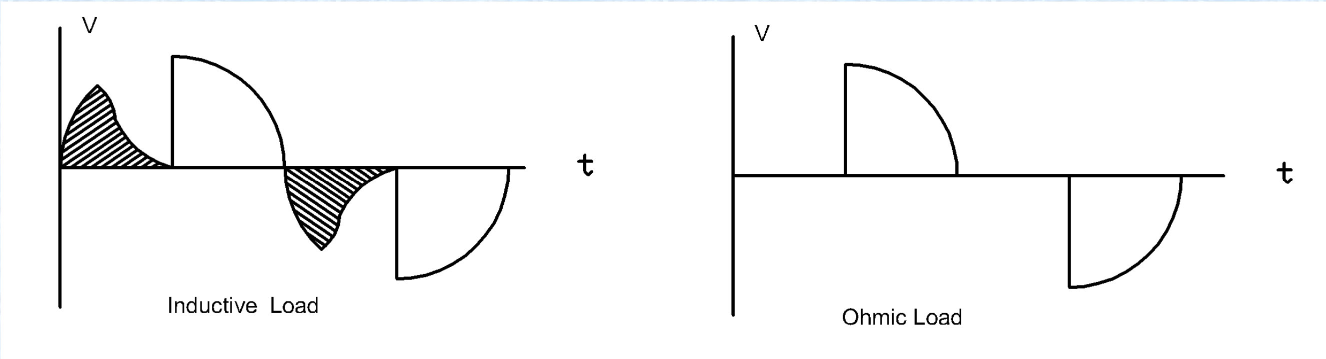
## *Design and implementation of an intelligent 3-phase, programmable soft-start controller, for low voltage induction motors*

*Our work in a snapshot:*

- Our purpose is to gradually increase the voltage output, in order to start an induction motor smoothly, by reducing the starting current.
- Voltage control of the induction motor is achieved by semiconductor switches (Triacs).
- Due to the inductive character of motors the control of semiconductor switches is lost from the system during the quenching time period.
- We tackle this phenomenon by adopting fuzzy logic, designed to determine the onset of the appropriate ignition pulse applied on the gates of the semiconductor switches.



## Asynchronous 3 ~ squirrel cage induction motor

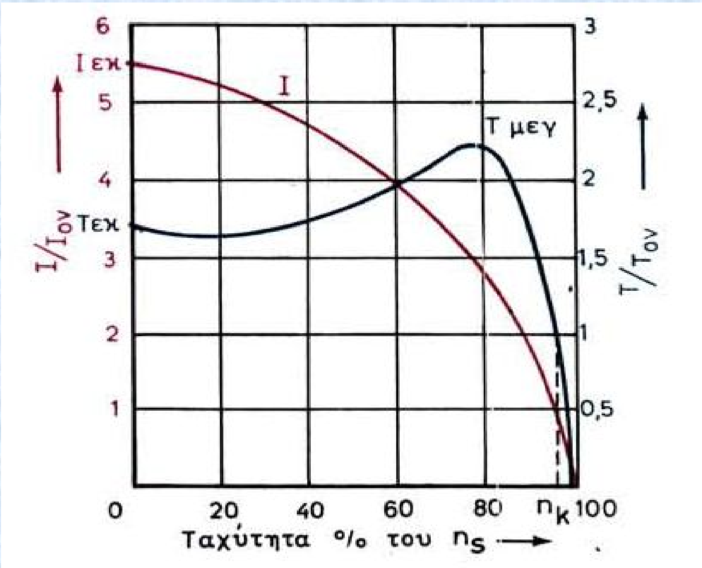
Today, asynchronous motors find wide application and are used by 95% in electric drive applications.

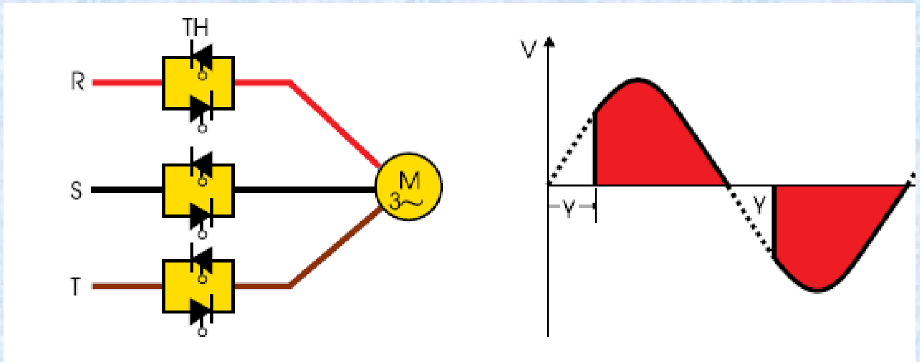
- **Disadvantages**

1. It is not possible to adjust speed-torque by simple means.
2. They are driven by very high starting current.

- **Methods of starting**

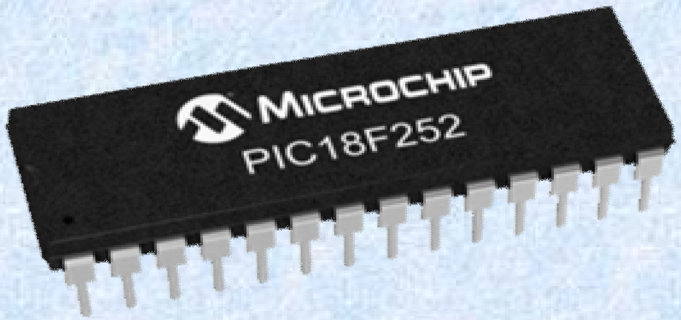
1. Starting with Y-Δ switch $[I_Y = I_\Delta / 3]$
2. Starting with resistors in stator winding
3. Starting with autotransformer
4. Starting by Power Electronics



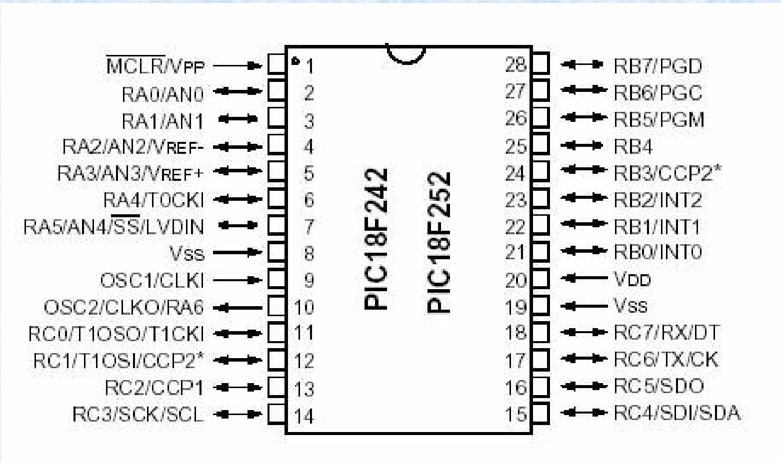
In modern soft-start applications a microprocessor undertakes the following:

- Controls the output voltage, by adjusting the value of the firing angle of thyristors or triacs.
- As a result, it regulates the current absorbed during startup.
- It can accept as a parameter the startup or deceleration time.
- It can determine an initial voltage for starting under load.
- Switches the system to the by-pass state, where the semiconductors are bypassed.



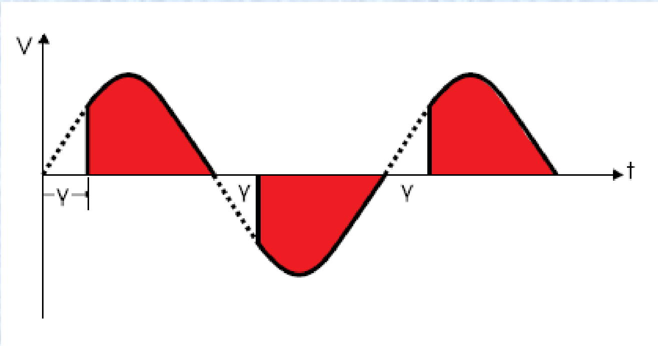
## The microprocessor PIC 18F252

- Small autonomous computer system programmed to perform a specific logic command sequence.
- Integrates the Harvard architecture, with different command and data bus (16bit / 8bit).
- Three I / O ports PORTA (7 pins), PORTB (8 pins) and PORTC (8 pins).
- It has four 8bit/16bit timers/counters (TMR0, TMR1, TMR2 and TMR3) and has WDT to reset the MCU.
- Multiple interrupt sources with adjustable priority.
- 1536 bytes of RAM memory to store temporary data and 256 bytes of EEPROM for permanent storage.

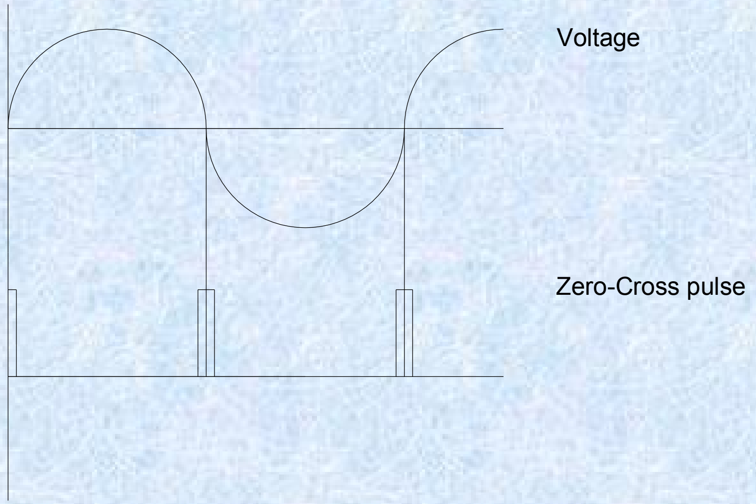


# Designing the soft starter - The zero cross pulses

- Voltage adjustment by controlling the period of time when the Triac is on

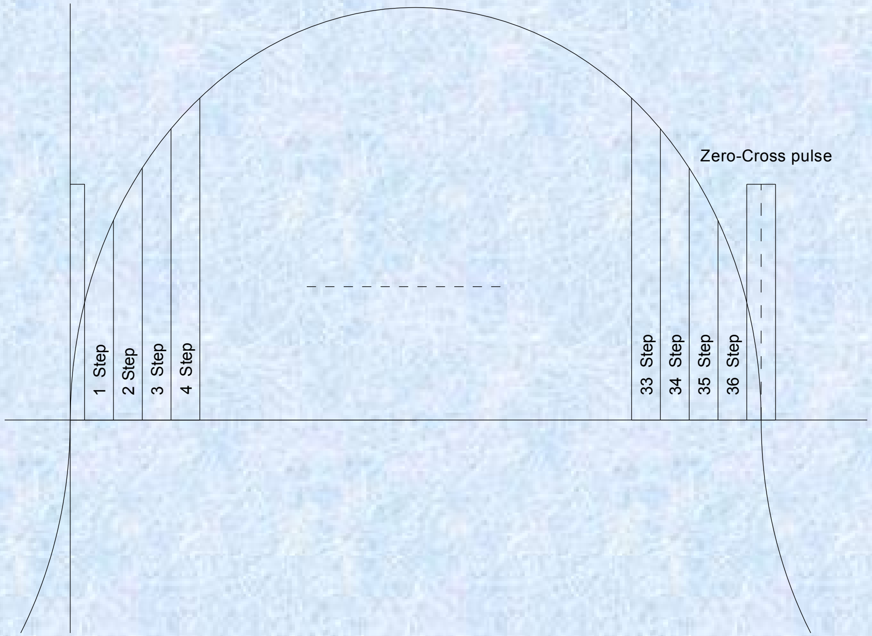



- Zero cross detection - zero-cross pulse



## The angular steps of our soft starter

- By increasing the ignition angle by predetermined steps, the starter voltage is gradually increased.




- The MCU logic is based on 36 consecutive overflows and reloads of TMR0.
- A counter is used for the counting of consecutive overflows.
- The MCU produces the ignition pulse when the number of overflows becomes equal to the decreasing number of the next step.
- The ignition pulse remains on until the end of the half-period.

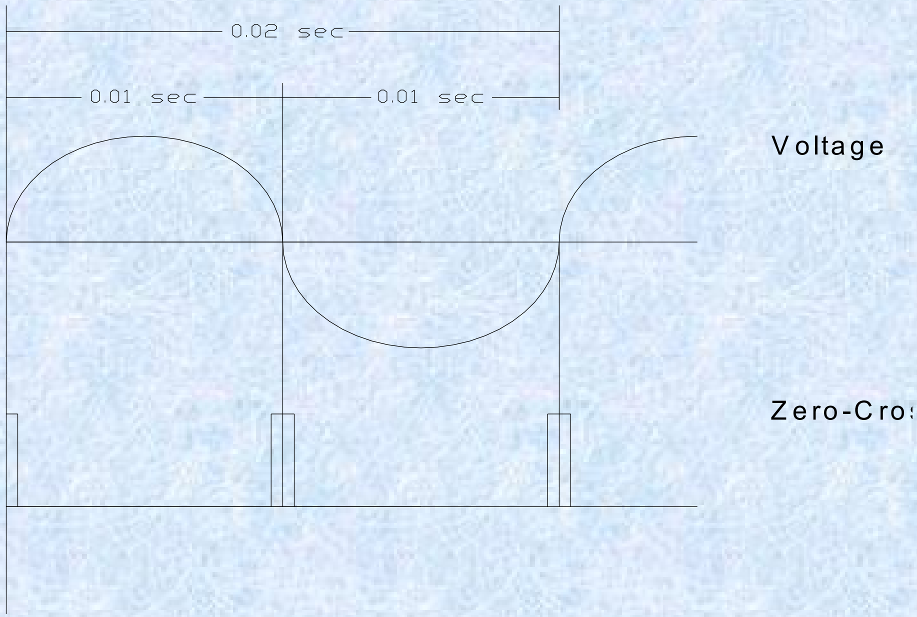
## The duration of the start-up process

- The start-up time is determined externally by the user using a parameter that takes value *N* via DIP switches.
- This parameter determines the number of alternations in each step.
- So the transition from the current step (for example the 30th) to the count-down step, (i.e. the 29th), occurs after *N* zero-cross pulses.

<u>Example:</u>

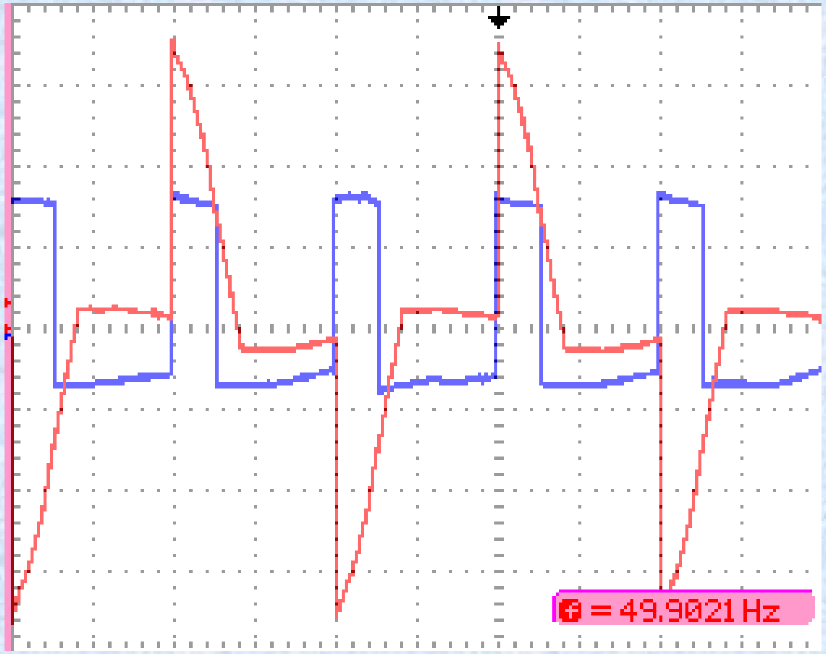
Total start-up time=Step Number x N x z-c pulse period =

= 36 x 30 x 0.01 sec = 10.8 sec

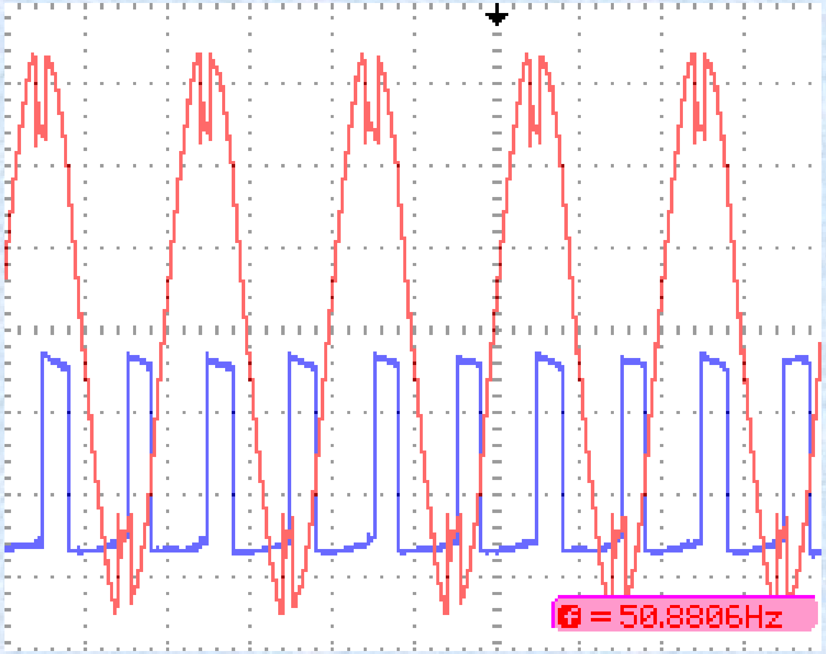


## The output of the soft starter without fuzzy logic

- Ohmic load



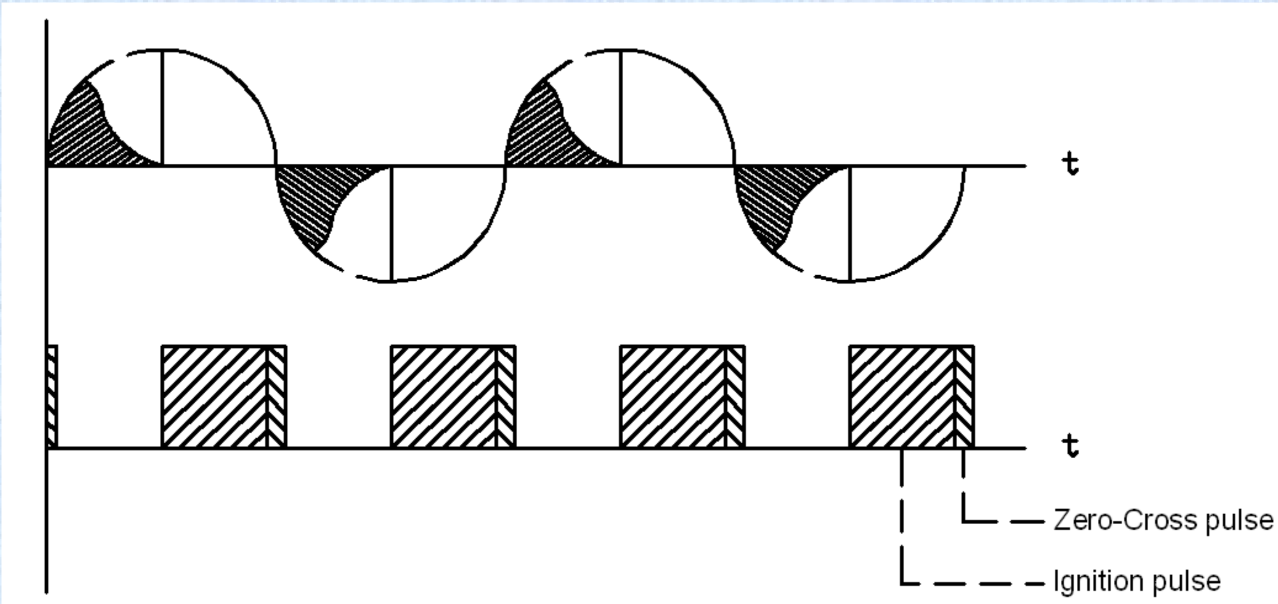

- Inductive load



## Tackling of the early starting effect.

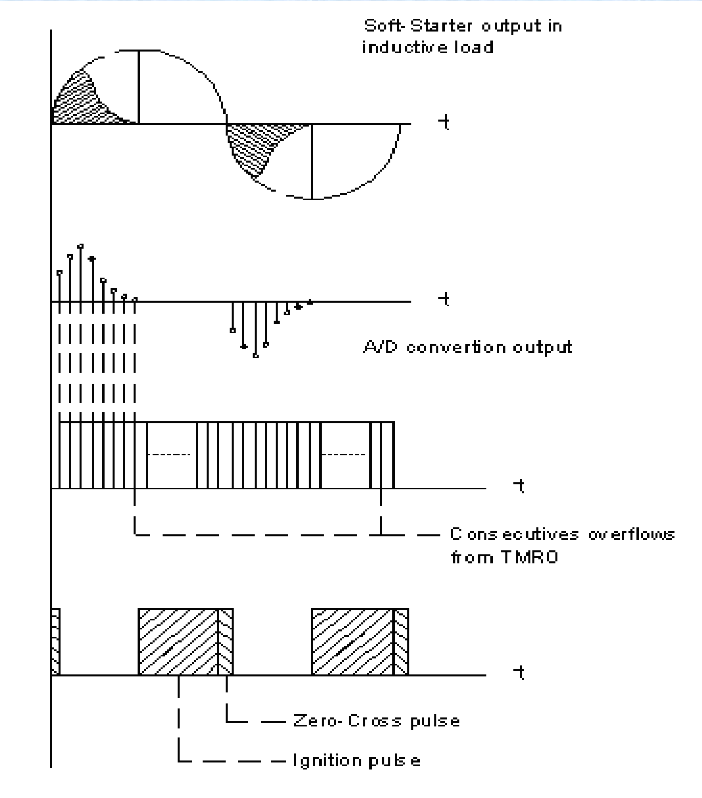
Suggested solution to the problem of early starting of the motor:

- Redefinition of transition time to the next step, based on the measurement of the mean value of the residual voltage that occurs during the quenching period of time.
- Measurement of the voltage in the hatched area using an ADC.
- Adoption of fuzzy logic.



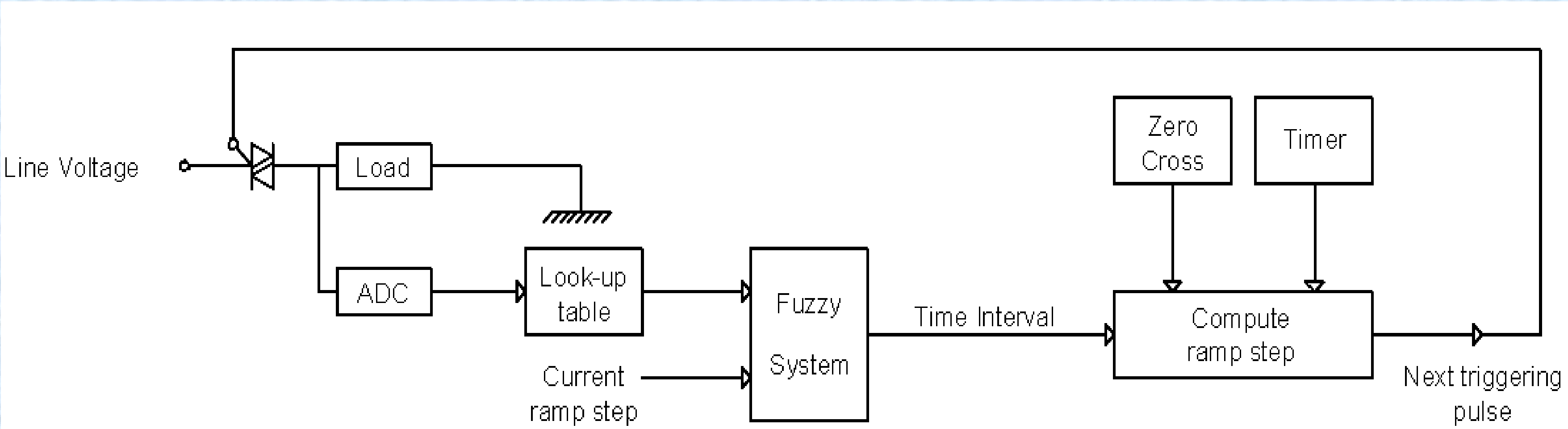
# Measurement of residual voltage using an ADC

- A residual voltage appears in the region of the alternation that corresponds to the quenching of the controlled voltage. The non-quenching of the switching semiconductor is attributed to the induction of the motor. The residual voltage is measured using an ADC.
- Due to the residual voltage, the output voltage precedes the expected output value and causes an earlier motor acceleration. This precedence can be described as an “effective angular step”. The mapping of the ADC measurement to this effective value is done with the help of a LUT.




The input to the ADC from the voltage sensor.

# Block diagram of the system

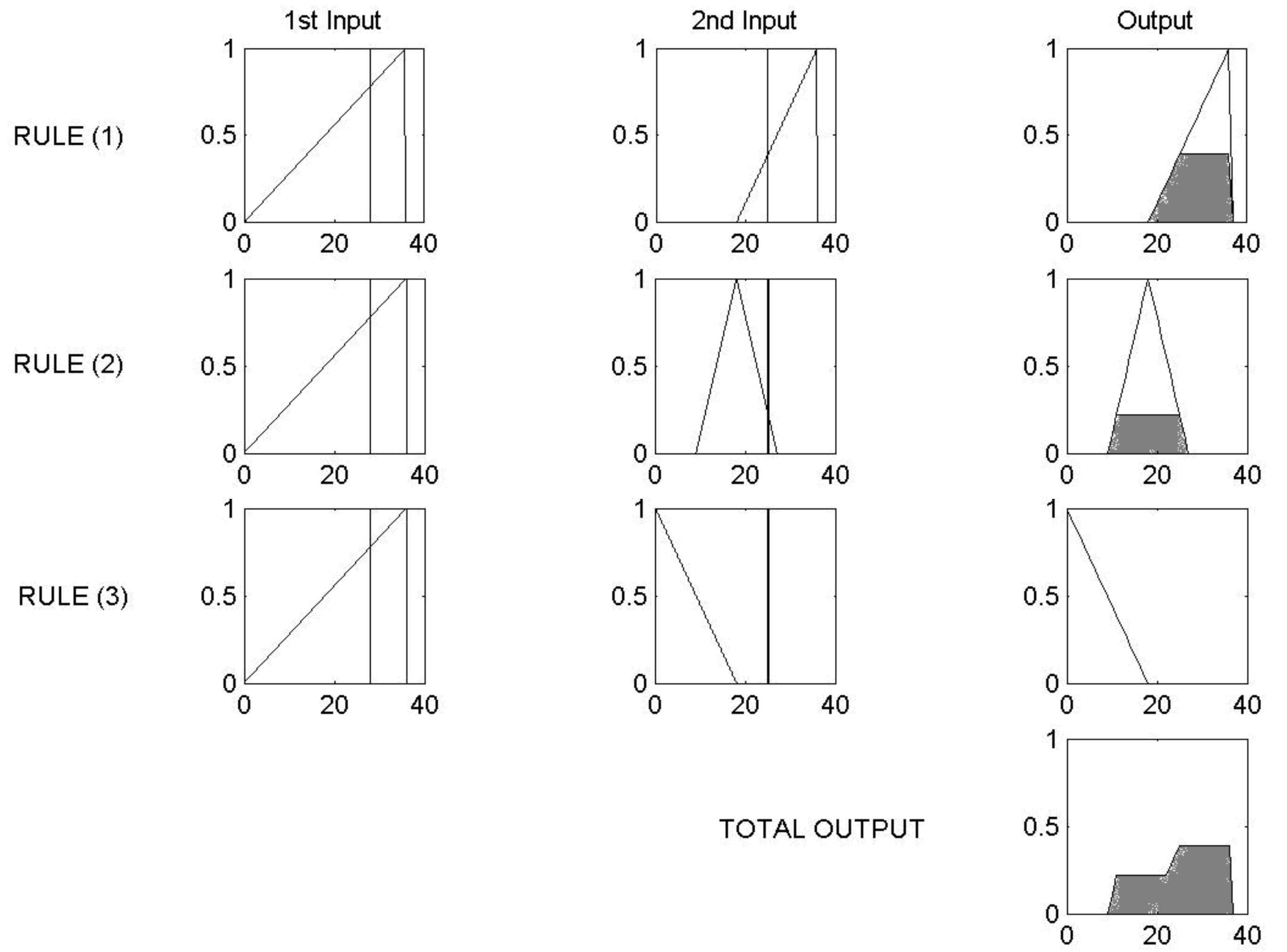



- The first input to the fuzzy system is the current angular step.
- The second input originates from a LUT that maps the ADC measurement to a value expressing the step precedence because of the residual voltage.
- The output is the next counter step that will change the ignition angle.

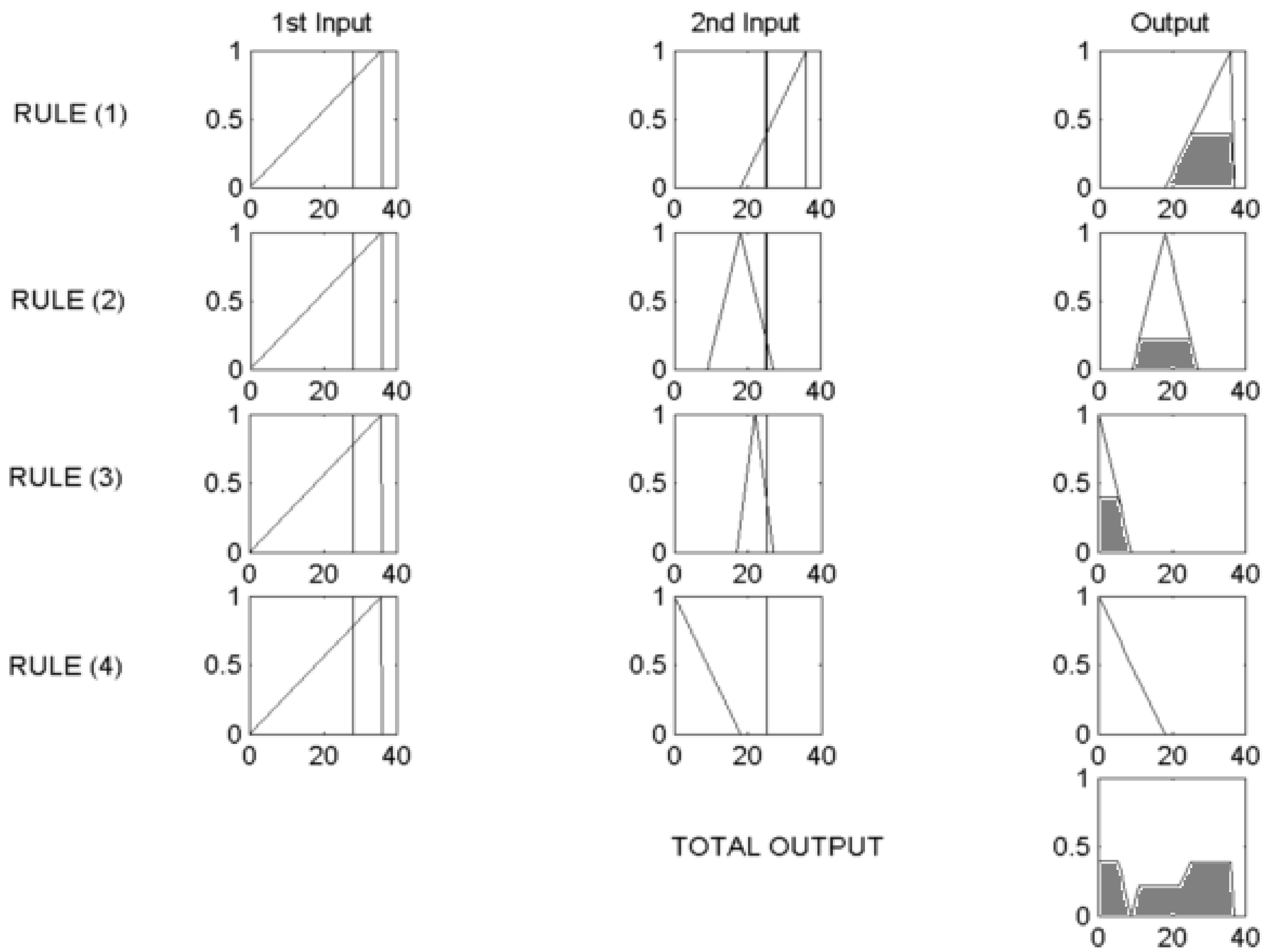
## The rules of the fuzzy system

- The fuzzy system operates with 3 rules.
- The inputs and output membership functions have a triangular form.
- The rules of the fuzzy system use the inference mechanism (operator) max-min of Mamdani.
- The total output has a crisp value using the Center Of Area (COA) defuzzyfication process

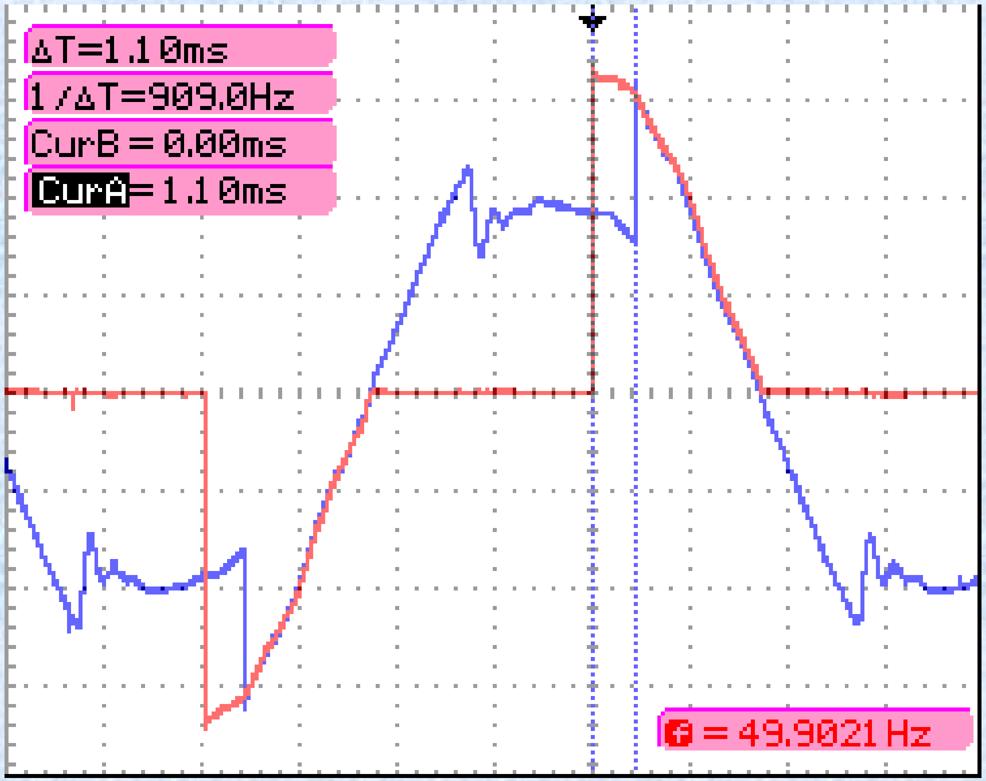
# Graphical representation of the fuzzy system with 3 rules



# Graphical representation of the fuzzy system with 4 rules



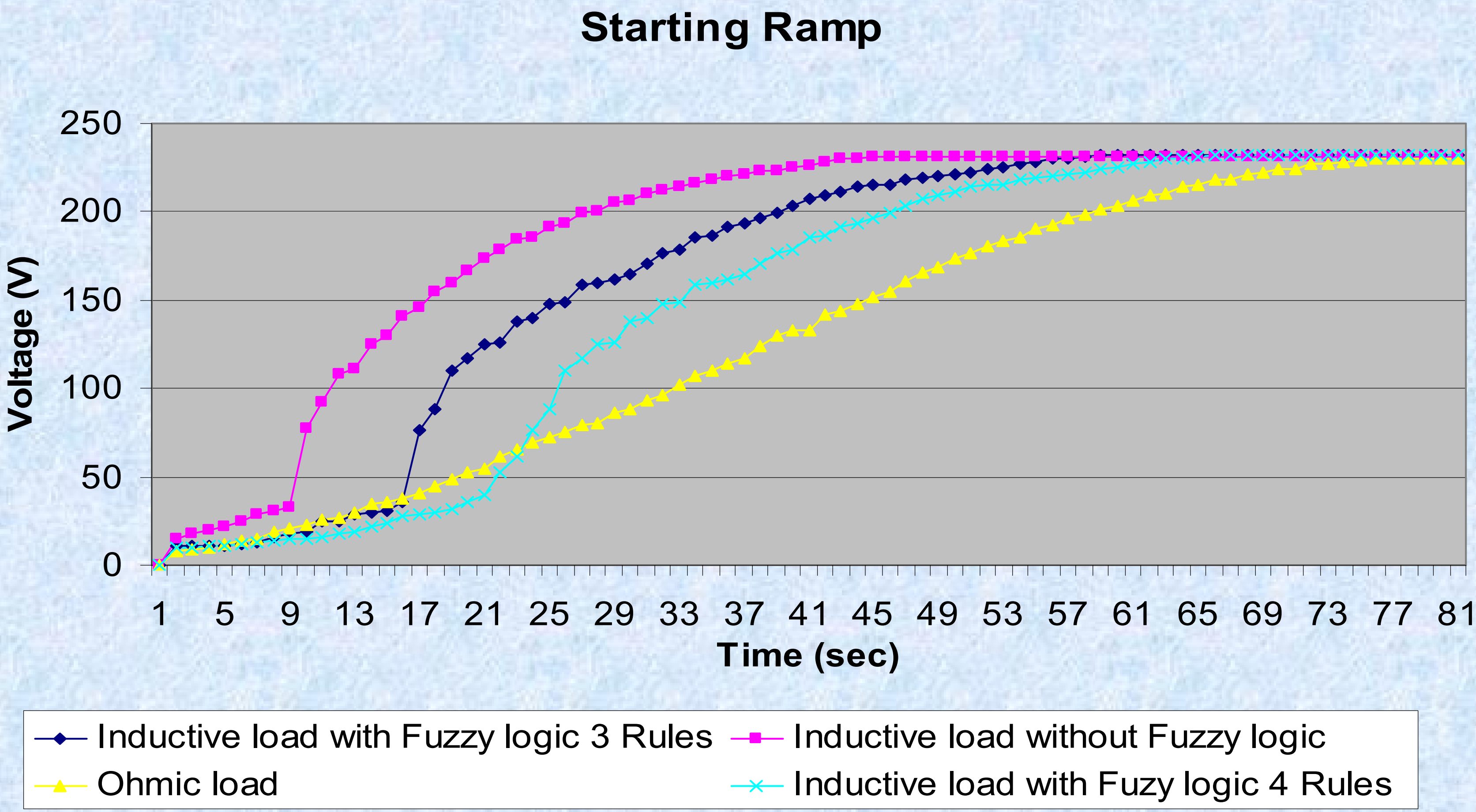
# The influence of the fuzzy logic in the evolution of the soft starter steps




The system change the evolution of the soft starter steps.

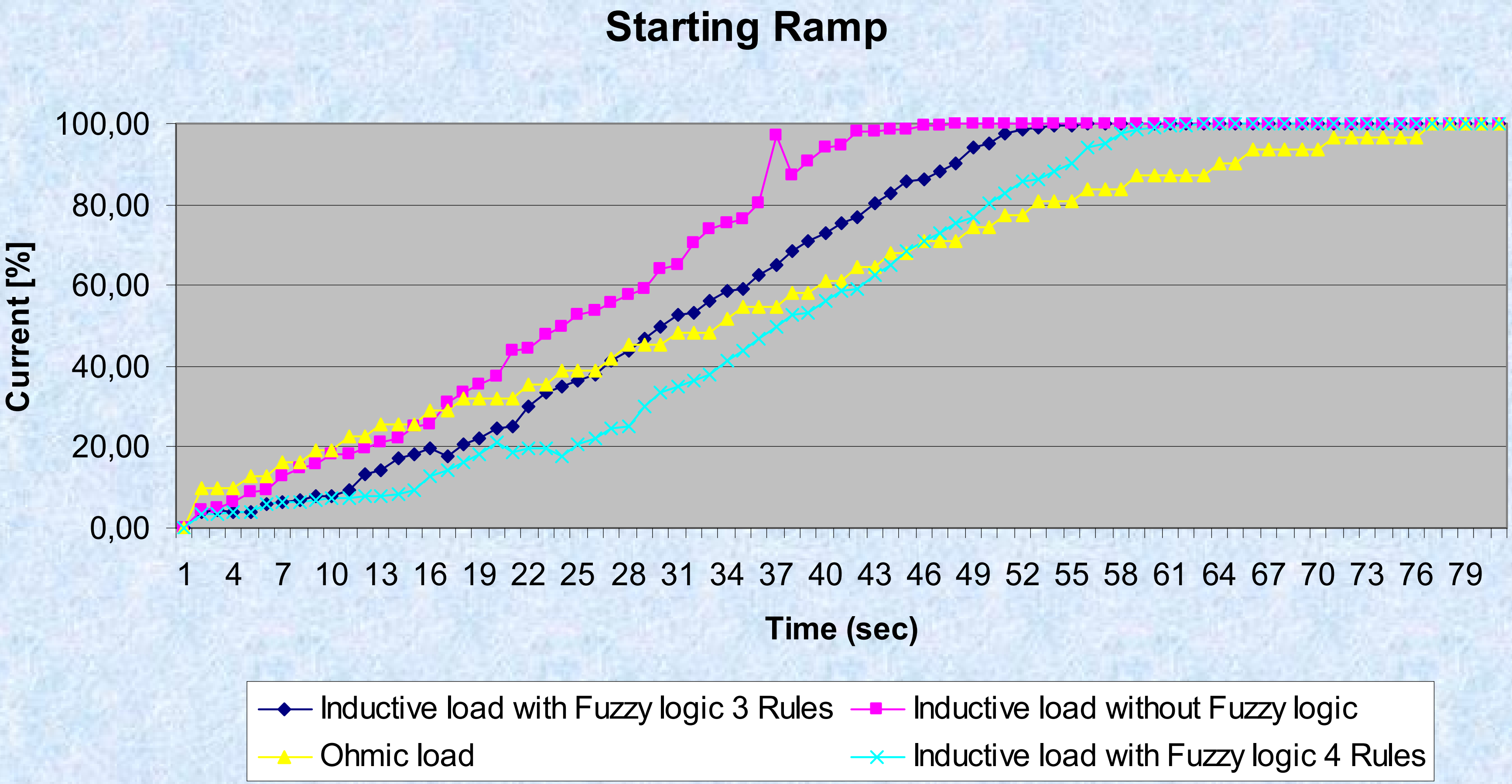
# The form of the rise ramp voltage of the soft starter

- Graph of starter ramp resulting from the weighted steps of the output voltage.



# The form of the rise ramp current of soft starter

- Graph of starter ramp resulting from the starting current normalized to unity.



# Conclusions

- The system offers an intelligent management of 3~ loads, focusing on their startup process.
- The phenomenon of early start-up due to load inductance is limited by the adoption of fuzzy logic.
- This results in a change of the evolution of the soft starter steps.
- Due to the decrease in the slope of the starting ramp even greater energy savings are achieved.
- The system is implemented with a low cost, under 50 euros.
- The only MCU peripherals required are:

  - One channel of ADC and

  - The timer TMR0

# Publications

1. PACET

   Gregory Zigirkas and John Kalomiros, “Design of a fuzzy soft-start controller for low-voltage induction motors ”, 3rd Pan-Hellenic Conference on Electronics and Telecommunications, 8-9 May 2015, Ioannina, Greece

2. Journal of Engineering Science and Technology Review (JESTR)

   Gregory Zigirkas and John Kalomiros, “Design of a fuzzy soft-start controller for low-voltage induction motors ”, (will be submitted)

3. IEEE IDAACS

   Gregory Zigirkas and John Kalomiros, “An Embedded Fuzzy Controller for the Soft-Starting of Low-Voltage Induction Motors ”, The 8th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 24-26 September 2015, Warsaw, Poland