Twin Induction Machines Artificial Loading Without Mechanical Coupling

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***Abstract* – This article presents an artificial loading method for induction machines using industrial static frequency converters (VFCs), low cost programmable logic controllers (PLCs) for command and control and standardized communication protocols. Possible methods of artificial loading are presented in this paper. Induction machine full load testing is very difficult, especially at high power and almost impossible for vertical axis machines. Sometimes in case of high-speed machines, also the interconnection between them can be a difficult task. Bidirectional VFC utilization can't always be a solution for artificial loading because of high variations of grid power (voltage). Two identical IMs without mechanical interconnection driven by two identical DC bus interconnected VFCs artificial loading method is presented in this paper. The power circulation between the machines is performed via the common DC link. This opens the possibility to test machines with rated power notably larger than the lab power source rating. The rated artificial loading conditions are achieved without mechanical coupling, without VFC oversizing and using standard equipment.**

***Index Terms*—PLC, induction machine, artificial loading**

I. INTRODUCTION

THE Induction Machine is world wide spread and used. Due to its characteristics such as robustness, easy to maintain and low-cost, IMs are used in various applications. Finding the losses before full load utilization represents a first important step. However, the nominal power testing of these machines can be problematic due to the engineering problems that occur. Artificial loading seems to be a good solution for IM testing at rated current and nominal temperature. This way reaching the effective value of the current can be done by means of rapid transition from motor mode to generator mode and vice versa. Often this method can be difficult to achieve with widely used conventional equipment.

Testing by mechanical coupling (shaft loading) can often be too expensive or in some cases it cannot be practically realized (very large machines, vertical shaft machines or high speed machines). In literature, there are a lot of methods used to perform the artificial loading. One of these would be the use of the dual-frequency loading – Ytterberg method, which is a relatively old method. In this method a voltage system consisting of two different frequencies would supply the induction motor [1]-[5].

This would be difficult to implement with the industrial VFC which utilizes standard analog input/outputs and firmware.

Another method would be the dynamic thermal loading [6],[7]. Induction machine would pass very quickly from the motor mode to the generator mode. The average value of the electromagnetic torque will be small so as to cover only the mechanical losses. This method can be implemented either as torque control or as speed control. It is mandatory to operate around the nominal speed in order to obtain the rated mechanical losses [8].

In the torque control technique the offset torque reference should not be smaller than that corresponding to induction machine losses. This value will determine the speed of the shaft. Not knowing the exact value of the losses in the machine, represents the main drawback of this control technique. This way, it is very difficult to maintain a precise shaft speed.

Better results can be obtained utilizing the speed control method. A precise speed offset, amplitude and oscillating frequency can be easily done. This way the mean torque value will be adjusted by the machine, in such a way so to cover the losses. Both methods can be implemented with standard VFC and classical control topologies.

In this method (with a single IM and inverter) instantaneous active power oscillates, while the average power is almost constant. The DC bus voltage can dangerously rise over the allowable value if VFCs are used to perform artificial loading with oscillating reference. The use of an oversized DC link VFC capacitor may be a solution against exceeding the maximum DC voltage (as it is presented in Cap. III Experimental Work, Fig. 3, Fig. 4), but it is not a cost effective option. For standard series of VFCs (which are the most commonly used drives), increasing the DC-Link capacitance requires an additional effort. A bi-directional VFC allows the circulation of a certain amount of power through DC bus, into the grid, thus avoiding overloading the capacitors or DC overvoltage. The classical topologies of the VFC and matrix converter are used in this scope [9], [10]. In case of high rate of power oscillation, the grid voltage may vary significantly. In industrial sites these variations may

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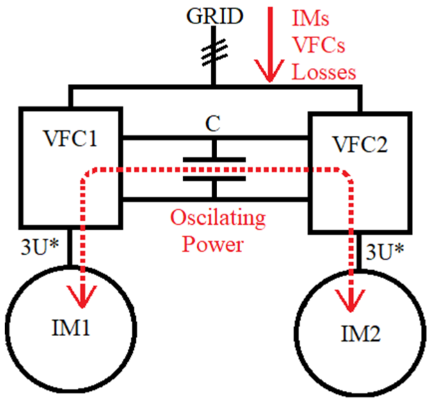

Fig. 1. Artificial loading with 2 DC-link coupled VFCs and 2 uncoupled IMs.

have undesirable effects like light flicker or incorrect operation of some other equipment in the building [11].

Fig. 1 presents the artificial loading method studied in this article. Two induction machines and two DC link coupled uni-directional standard VFCs are used. C represents the total parallel VFC DC capacity. Both VFCs and both IMs are identical. The IMs are speed controlled by the VFCs and are not mechanically coupled. The VFC speed reference consists of an offset and an alternative sinusoidal component. The power flows from one induction machine to another via both VFCs and through then common DC link. The grid connected rectifier diode bridge supplies the DC link with power necessary to cover the IMs losses.

II. Setup Configuration

The artificial loading methods presented above use either special equipment (VFC with special features), or require mechanical coupling. The method discussed in this article implies utilization of standard equipment used in the industry (such as VFC, PLC, standardized communication protocols) in order to perform artificial loading. Avoiding power injection in the grid creates the possibilities to perform the load testing in any area, without electrical pollution, and also reduces the artificial loading overall cost by means of uni-directional rectifier (diode) + VFCs. The advantage of using a standard VFC is that an industrial standardized electrical signal can be used as reference.

TABLE I
Induction Machines and Variable Frequency Converters Parameters

IM		VFC	
$Voltage$	$400[V]$	$Voltage_{IN}$	$3\sim380\ldots400[V]$
$Current$	$15.4[A]$	$Current_{IN}$	$32[A]$
$Power$	$7.5[kW]$	$Freq_{IN}$	$48\ldots63[Hz]$
$Speed$	$2880[rpm]$	$Voltage_{OUT}$	$3\sim0\ldots Voltage_{IN}\ [V]$
$\cos\varphi$	0.87	$Current_{OUT}$	$34[A]$
R_s	$0.41[\Omega]$	$Freq_{OUT}$	$0\ldots300[Hz]$
R_r	$0.77[\Omega]$	$Power$	$7.5[kW]$
L_m	$169.9[mH]$	-	-
L_s	$4.299[mH]$	-	-
L_r	$4.299[mH]$	-	-

This leads to the possibility of using a robust and low cost control system. The PLCs are stable at temperature variations, dust, vibration and electromagnetic pollution. They are cost effective in controlling complex systems, easy to maintain and can be programmed quickly with less manpower for design. The PLCs are wide spread on industrial platforms and use standardized communication protocols. They are often used in petrochemical, biomedical, oil and gas sector and can easily interface with other standardized systems [12].

This article focuses on artificial loading using standard industrial command and control equipment.

The three phase VFC1 and VFC2 are identical and are connected to the same grid. The VFC cannot inject power into the grid, being a system in two quadrants due to the rectifier bridge at the input. The inverter side is connected to the IM. VFC1 drives the IM1, and the VFC2 drives the IM2 without speed encoders. The VFC's DC buses are connected together by means of a contactor. The connection between the two converters is protected by the use of ultra-fast fuses. This way, the DC storage capacity is doubled. If the VFCs have DC bus charging current limitation, the DC coupling can be done before powering to the grid, otherwise the DC coupling is performed after the inverters are in operation. The IMs are not mechanicaly coupled. The speed reference is given to the VFC as a standardized 4-20mA signal. The PLC's performance is low, requiring only 2AI and 1AO. The speed reference offset is set directly into the VFCs, in order to use only one PLC AO ports to control both inverters.
The oscillating speed references without offset are:

$$PLC^{*}_{reference} = \pm Amp \bullet \sin(\omega t) \qquad (1)$$

In Fig.2 the final speed references applied to the VFCs processors are presented.

$$speed^{*}_{VFC1} = VFC1_{internal\ reference} + PLC^{*}_{reference} \qquad (2)$$

$$speed^{*}_{VFC2} = VFC2_{internal\ reference} - PLC^{*}_{reference} \qquad (3)$$

Where: $PLC^{*}_{reference}$ is the alternating reference prescribed by the PLC, Amp is the amplitude of the sine reference, ωt is the reference frequency, $speed^{*}_{VFC1}$, $speed^{*}_{VFC2}$ is the speed reference prescribed to VFC1 respectively to VFC2 and $VFC1_{internal\ reference}$, $VFC2_{internal\ reference}$ are the internal set speed offsets of the inverters.

Due to the variation of the speed reference frequency, the effective value of the current is determined inside the PLC by means of filtered VFC RMS currents. The internal limitations of PLC memory needs that RMS current to be computed on smaller intervals.

$$I_{rmsVFC1} = \sqrt{\sum_{i=1}^{\frac{n}{m}} \left(\frac{\sum_{k=1}^{m} I^{2}_{VFC}}{n} \right)} \qquad (4)$$

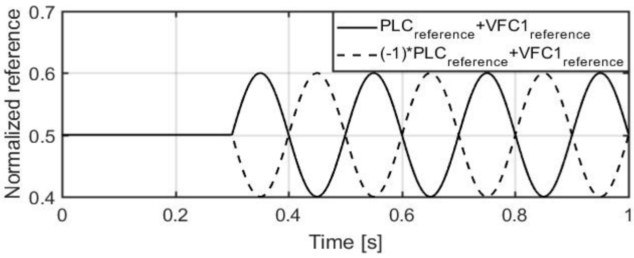

Fig. 2. PLC reference + VFC Internal reference (VFC1,VFC2)

where: $I_{rmsVFC1}$ represents the RMS current computed in PLC, I_{VFC} represents the filtered RMS current read from VFC, n represents the number of samples used to calculate the RMS value, m represents the number of samples in one subinterval, $\frac{n}{m}$ represents the number of subintervals.

The induction machines currents, the DC voltage and the current absorbed from the grid are measured using an oscilloscope.

III. Experimental Work

A. *Limitations of artificial loading of 1 Induction Machine with 1 Variable Frequency Converter (and one DC capacitance)*

1) The 7.5kW IM is driven by one 7.5kW VFC

This way the VFC receives a sinusoidal speed reference from PLC. The offset component of the reference is set inside the VFC. The IM is fed by the VFC. In Fig. 3 it can be observed that the DC link voltage variations are very high, reaching close to the maximum allowable DC voltage. This is an unacceptable limitation. The IM RMS current value is given as the last term in the graph legend.

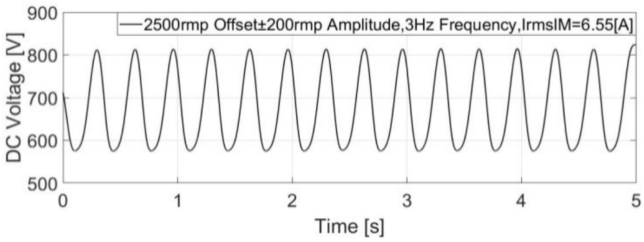

Fig. 3. Filtered DC Voltage variation for a 1 IM and 1 VFC - measured

2) The 7.5kW IM is driven by one 7.5kW VFC with doubled DC capacitance.

This way the second VFC is utilized just to double the DC storage capacity. In case of an oversize VFC (two VFC DC connected together), the DC voltage varies less, but still has big variations Fig.4. In Fig. 5 and Fig. 6 (zoom) unfiltered DC voltage, filtered DC voltage and the grid current which is absorbed by the VFC are presented.

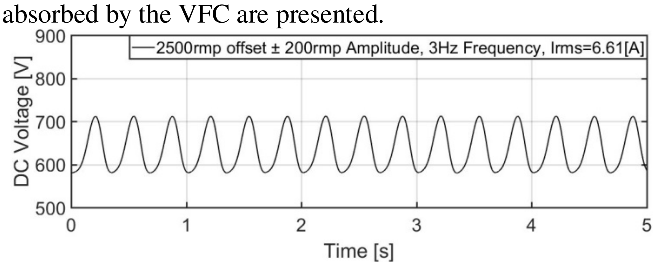

Fig. 4. Filtered DC Voltage variation for a 1 IM and 1 VFC (oversized DC capacitor) - measured

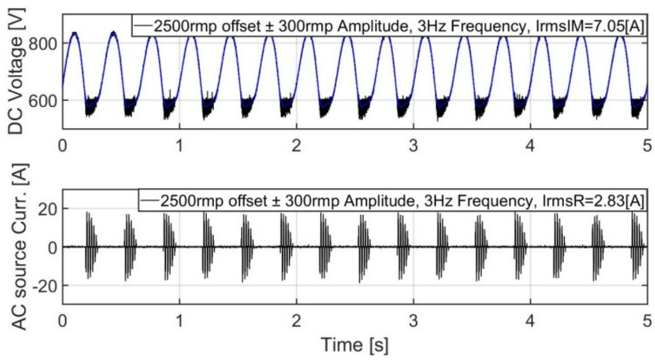

Fig. 5. Unfiltered and Filtered DC Voltage variation and diode rectifier input current for a 1 IM and 1 VFC (oversized DC capacitor) - measured

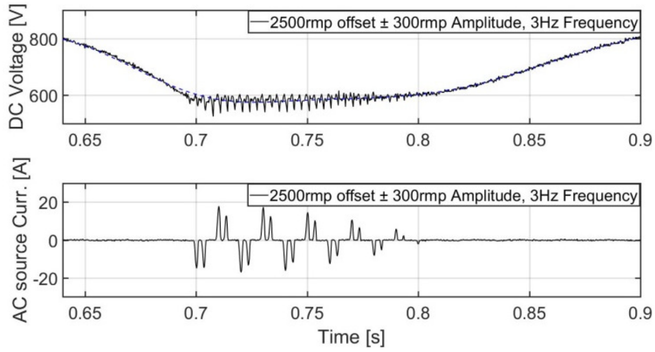

Fig. 6. Zoom on Unfiltered and Filtered DC Voltage variation and rectifier absorbed current for a 1 IM and 1 VFC (oversized DC bus) - measured

Increasing the reference amplitude or the reference frequency are two possibilities to increase the IM RMS current. Even if we double the DC storage capacity, the IM's current cannot reach the rated current.

The RMS current can be obtained by modifying both amplitude and frequency of speed reference oscillations. Changing a single parameter at once is insufficient to achieve the nominal value of the current.

Above a certain frequency limit, the inertia of the IM filters the speed. Fig. 7 shows the limitations in current increasing by exceeding a frequency limit value. The test was performed at 2500rpm offset speed reference and 200rpm amplitude of speed oscillation reference. In this case the maximum obtained RMS current is just 71% of rated RMS current.

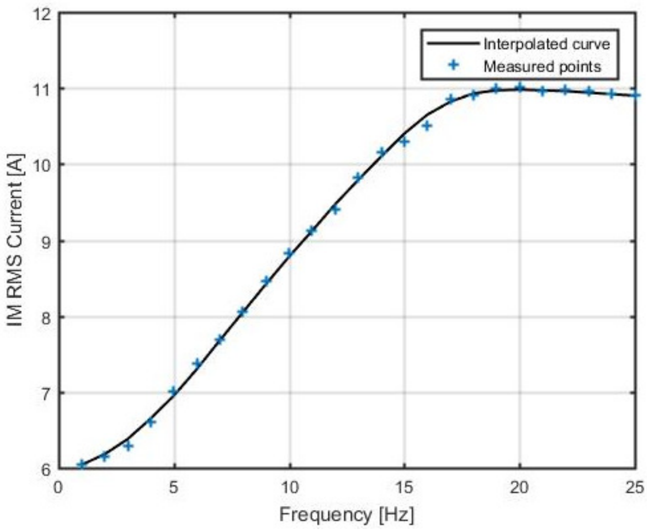

Fig. 7. IM frequency response for a 1 IM and 2 VFC (oversize DC capacitor) - measured

B. Artificial loading: 2 Induction Machines, 2 DC interconnected Variable Frequency Converter

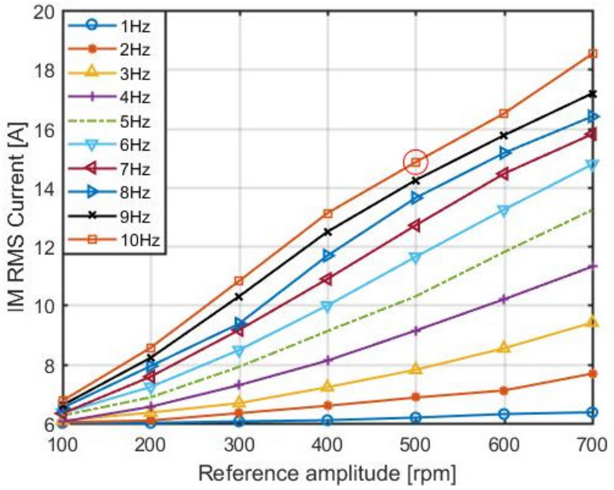

Fig. 8. The RMS current for artificial loading with 2 IM and 2 DC connected VFCs.

In order to extend the artificial loading range while reducing the dc link voltage oscillations and the ac source input current in front of the diode rectifier, this paper presents **artificial loading using two identical motors driven by two identical unidirectional converters coupled in the DC link**. Power circulation is done from one machine to another via first VFC then through the DC link and then through second VFC. Both VFCs drive the machines simultaneously, when one of them accelerates (motor mode) another one brakes (generator mode) and vice versa (Fig.2).

The IMs RMS currents can be modified depending on the reference speed variation: amplitude and frequency. The rated RMS current can be obtained in different ways. Fig. 8 presents the current variations for 10 different reference frequencies and 7 different reference amplitudes of speed oscillations. The circled point on the graph represents the nearest point to rated conditions, were the test was performed. The maximum amplitude of speed reference was chosen as the synchronous IM speed for safety reasons.

The Induction machine thermal testing can be done manually or automatically using the same setup. The alternating speed reference is also given by the PLC, while the offset is set internally into the variable frequency converters.

1) Open loop loading method

In open loop the reference speeds amplitude and frequency are given manually taking into account the RMS currents from both induction machines and the DC bus voltage. This way the machines were loaded at rated RMS current by increasing gradually the amplitude and frequency of the speed reference. Fig. 9 presents the DC voltage, the rectifier input current, and the currents absorbed by both machines at full load conditions. With this method the reference should be modified slowly, in order to reach the rated current, to avoid DC bus overvoltage. At the same time it offers a better control of IMs and VFCs behavior.

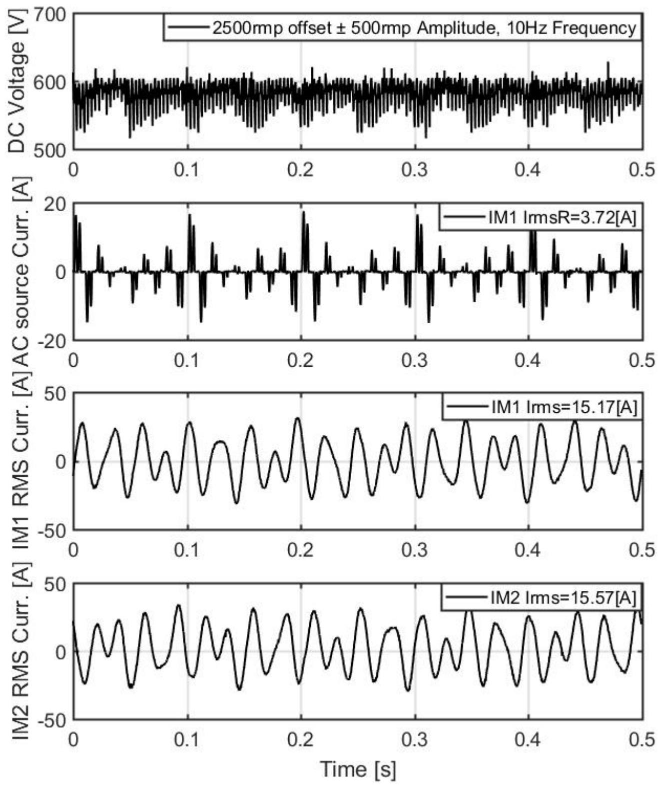

Fig. 9. Rated RMS current artificial loading with 2 IM and 2 DC connected VFC - measured

2) Closed-loop loading

The current closed-loop method (Fig.10) can be used to perform the artificial loading with 2IMs and 2 DC connected VFCs. It is based on the same reference generator implemented on PLC. In this case the PLC cyclic time is set to 1ms (as small as possible) in order to ensure a stable operation of the regulators.

By means of a PI regulator the speed reference is transformed into amplitude and sine frequency. The maximum value of the reference is given in saturation blocks. The integrator block performs also the sin argument range limitation. This limitation is necessarily implemented into PLC to avoid stack overflow. The method has the advantage that the VFC speed reference (and current) is automatically smoothly increased by modifying the amplitude and the frequency (Fig. 11).

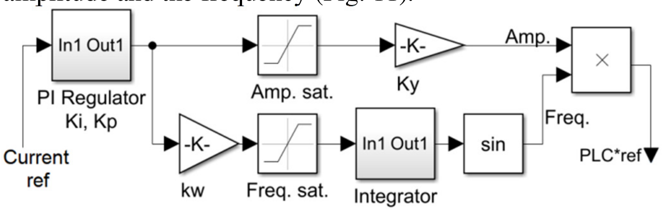

Fig. 10. PLC implemented current closed-loop regulators

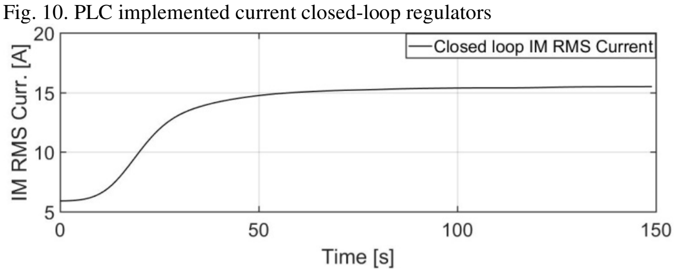

Fig. 11. Closed loop artificial loading for 2 IM and 2 DC connected VFC - measured.

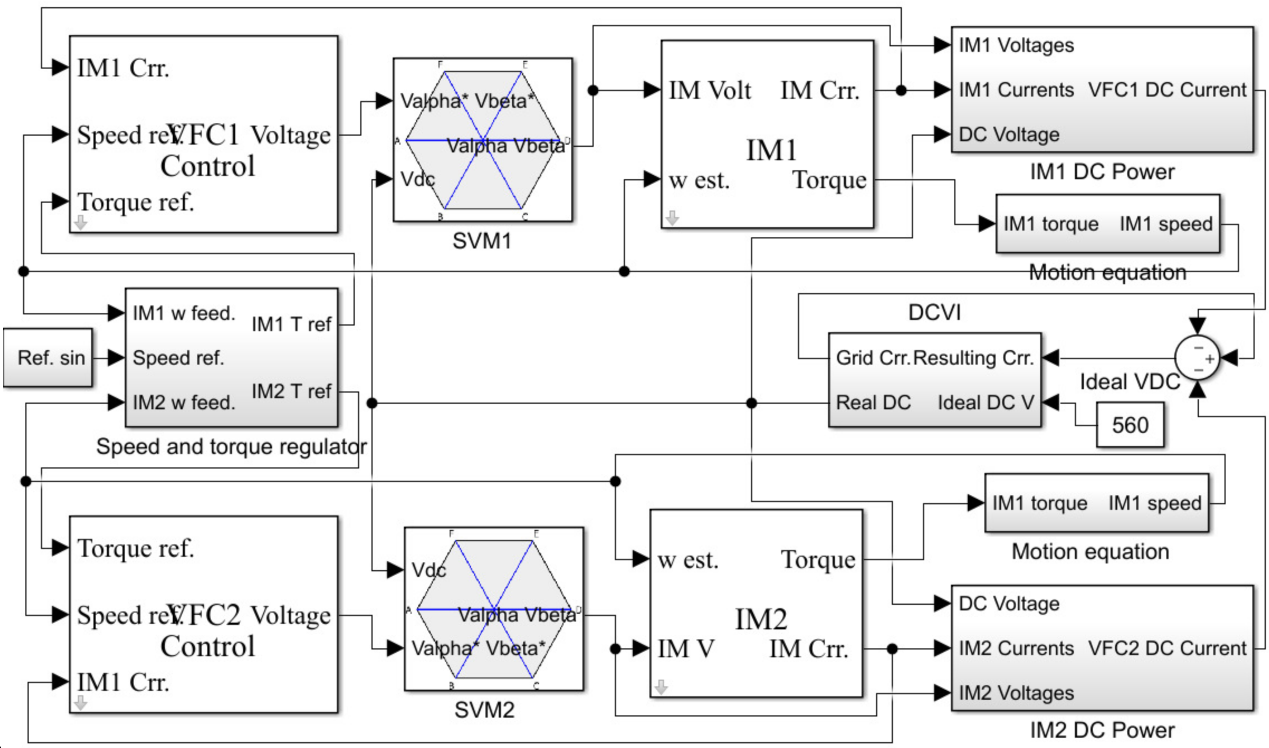

Fig. 12. Artificial loading with 2 IM and 2 DC connected VFC- Simulink implementation

IV. Artificial Loading Simulations

The Simulink block diagram for the system is presented in Fig. 12. The simulation of artificial loading test is performed in Simulink and offers information about the behavior of the VFCs and IMs, here-tested. In order to validate the artificial loading method efficiency, simulations at rated power and artificial load were performed. The results are presented below. The sine wave reference is given to the Speed and torque regulator block Fig.12. This block contains the PI regulator for automatic loading and produces torque reference. In order to close the speed loop, the estimated speed from both induction machines comes into this block. To control the machines, sinusoidal voltages are created by VFC block, which simulates the variable frequency converters. The main purpose of simulations is to discuss the loss equivalence procedures so needed when this method is used to determine efficiency.

The DC connection of the two VFCs is implemented in SVM blocks which realize a space vector modulation with estimated DC voltage from DCVI block. The dynamic effects of the VFC were taken into account in this block. The total DC bus capacitance and equivalent DC filter inductances are used to obtain the DC currents and voltages in the DCVI block (Fig 12). The IMs power is found in VFC and is transformed into DC current in IM DC Power blocks. The sum of the two DC link currents and the total capacitance current represents the diode rectifier output current. The diode rectifier output current reflects the AC currents in the input of the diode rectifier, and indirectly the power losses of the two IMs and their VFCs. The losses in the VFCs are neglected in the simulation program, for simplicity only. The IMs equations are:

$$\dot{\Psi}_{\alpha s} = U_\alpha - a_{11}\bullet\Psi_{1s} + a_{12}\bullet\Psi_{1r} \quad (5)$$

$$\dot{\Psi}_{\beta s} = U_\beta - a_{11}\bullet\Psi_{2s} + a_{12}\bullet\Psi_{2r} \quad (6)$$

$$\dot{\Psi}_{\alpha r} = a_{21}\bullet\Psi_{1s} - a_{22}\bullet\Psi_{1r} - p\bullet\omega\bullet\Psi_{2r} \quad (7)$$

$$\dot{\Psi}_{\beta r} = a_{21}\bullet\Psi_{2s} - a_{22}\bullet\Psi_{2r} + p\bullet\omega\bullet\Psi_{1r} \quad (8)$$

$$I_{\alpha es} = c_1\bullet\Psi_{1s} + c_2\bullet\Psi_{1r} \quad (9)$$

$$I_{\beta es} = c_1\bullet\Psi_{2s} + c_2\bullet\Psi_{2r} \quad (10)$$

$$I_{\alpha er} = c_2\bullet\Psi_{1s} + c_3\bullet\Psi_{1r} \quad (11)$$

$$I_{\beta er} = c_2\bullet\Psi_{2s} + c_3\bullet\Psi_{2r} \quad (12)$$

$$\sigma = 1 - \frac{L_m^{\ 2}}{L_s * L_r}; \quad (13)$$

$$a_{11} = \frac{R_s}{\sigma * L_s}; \quad (14)$$

$$a_{12} = R_s * \frac{1-\sigma}{\sigma * L_m}; \quad (15)$$

$$a_{21} = R_r * \frac{1-\sigma}{\sigma * L_m}; \quad (16)$$

$$a_{22} = \frac{R_r}{\sigma * L_s}; \quad (17)$$

$$c_1 = \frac{1}{\sigma * L_s}; \quad (18)$$

$$c_2 = \frac{\sigma - 1}{\sigma * L_m}; \quad (19)$$

$$c_3 = \frac{1}{\sigma * L_r}; \quad (20)$$

where: $\dot{\Psi}_{\alpha s}, \dot{\Psi}_{\beta s}, \dot{\Psi}_{\alpha r}, \dot{\Psi}_{\beta r}$ are stator and rotor α, β-axis time derivatives of ortogonal flux components, p is the number of pole pairs, ω is the shaft speed, R_s, R_r are the stator and rotor resistance, L_m, L_s, L_r are magnetizing, stator, respectively rotor inductances, $U_{1s}, U_{2s}, U_{1r}, U_{2r}$ are the stator and rotor voltages, U_α, U_β are the stator α, β-axis voltage components, $I_{\alpha es}, I_{\beta es}, I_{\alpha er}, I_{\beta er}$ are the stator and rotor α, β-axis estimated current components, $a_{11}, a_{12}, a_{21}, a_{22}, c_1, c_2,$ c_3, σ are coefficients. The equations (5)-(20) implement the dq-model in stator coordinates.

The SVM blocks give the voltages to the IMs. The IMs speed (ω) is estimated in Motion equation blocks. In this simulation the grid voltage is simulated by using an ideal rectifier (block Ideal VDC).

The power losses are computed in IMs for both the rated actual (shaft) load torque and artificial rated loading. In Fig. 13. the IMs AC currents for both induction machines, the DC rectified current and the DC voltage are presented, in artificial loading simulation with real speed reference parameters: 2500rpm speed offset, 500rpm amplitude and 10Hz frequency.

The oscillations in the DC rectified current Fig 13 are due to the insufficient voltage when one motor is accelerated to a high speed. A reduction of flux reference in the IMs would reduce these oscillations to a fairly small value.

In Fig. 14 the losses obtained from simulation at artificial loading with 2 IMs and 2 DC connected VFCs are presented.

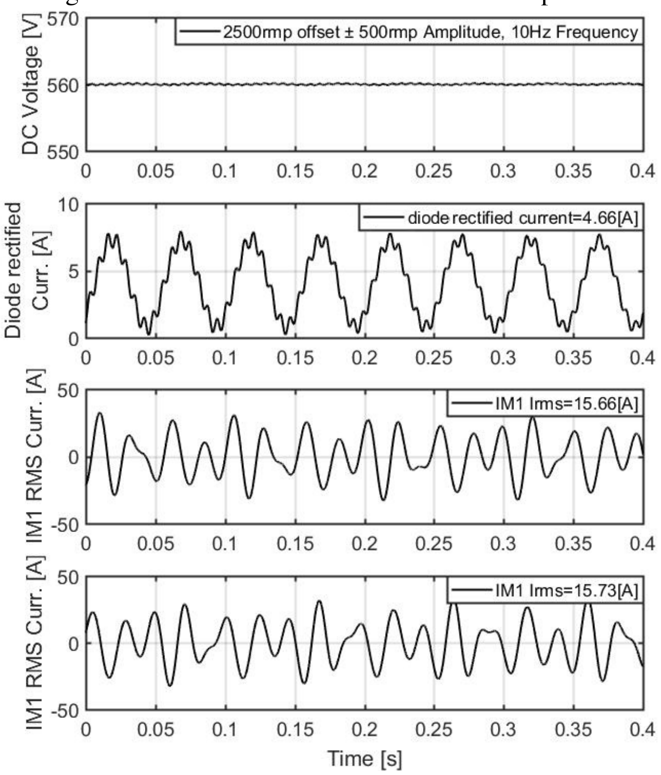

Fig. 13. DC Voltage, diode rectified current and IMs currents for simulated artificial loading with 2IMs and 2DC connected VFCs

Fig. 15. presents the IM instantaneous current at rated power and the current RMS value. The artificial loading method validation is done by comparing the results obtained at rated shaft torque with those obtained in artificial loading corresponding to the approximate same IM RMS currents. Figure 15 presents the losses in this situation.

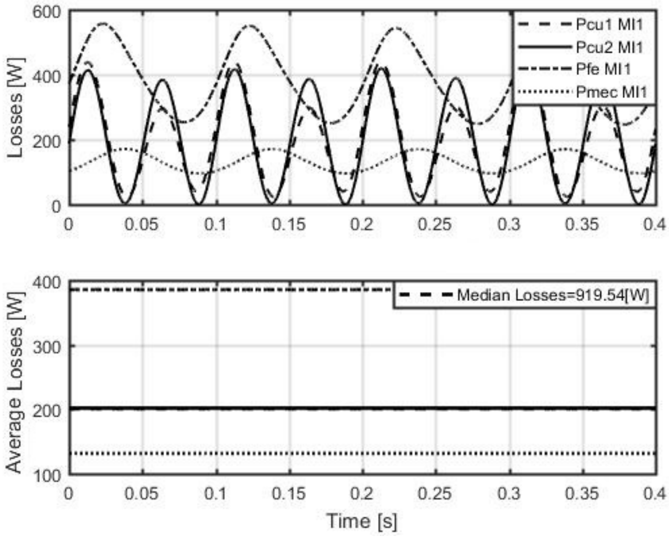

Fig. 14. Instantaneous and average mechanical, iron and copper losses in one IM for simulated artificial loading with 2 IMs and 2 DC VFC.

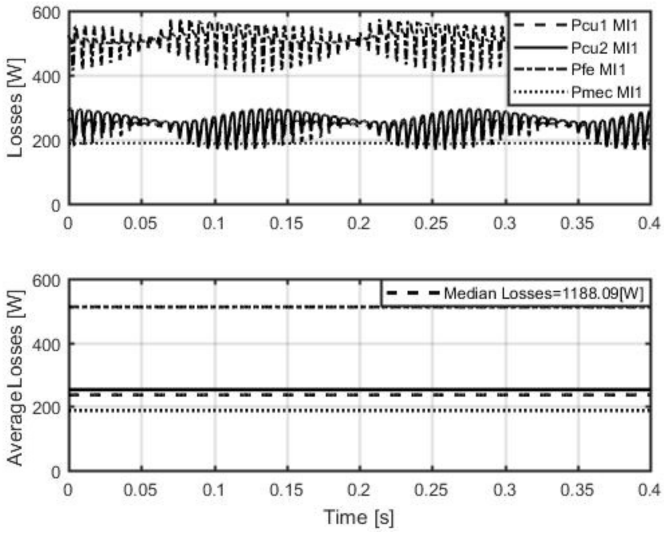

Fig. 15. Instantaneous and average mechanical, iron and copper losses in one IM for simulated nominal shaft loading with 1 IM and 1 DC VFC.

Figures 14 and 15 show a fairly acceptable agreement of losses for artificial and shaft full load, but more work is needed to equal the equivalent mechanical and core losses at variable speed in artificial loading with those at constant speed in shaft loading.

V. Conclusions

In order to allow for more than rated current artificial loading of IMs, a twin machine + VFC system is proposed were the DC links are put in parallel and fed through a diode rectifier.

It is first demonstrated experimentally that for a single machine artificial loading, the DC overvoltage is unacceptable, even at 40% rated current.

The twin machine artificial loading is shown experimentally to not create DC over voltages, even at 120% RMS current. Besides experimental work, a digital simulation code was developed, where, with a good approximation, the losses on a single machine in the proposed twin machine artificial loading scheme are equal to those when actual shaft loading at same IM current is simulated.

Also the paper introduces a slow close loop current control, besides open loop operation, which commands reference speed synchronous oscillations for the two motors. This way the whole testing efficiency for various loads may be automatized.

More work related to loss equivalence for artificial versus actual shaft loading testing is to be done in the near future to fully validate the proposed solution.

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VII. References

[1] Lucian Tutelea, Ion Boldea, Andrew Ewen Ritchie, Per Sandholdt, Frede Blaabjerg," Thermal Testing for Inverter-Fed Induction Machines using Mixed Frequency Method", Proceedings of International Converence on Electrical Machines, ICEM'98, Istanbul, Turkey, Sept. 1998.

[2] H. R. Schwenk, "Equivalent loading of induction machines for temperature tests", IEEE Transaction on Power Apperatur and Systems, Vol. PAS-96, no.4, July/August 1977.

[3] S. Garvey, I kolak M.T Wright, "Aspect of mixed frequency testing for induction machines", Record of ICEM-1994, D14, Paris, France.

[4] I Boldea, T. Lucian, N. Muntean, "A new approach to inverter-fed mixed frequency testing of induction machines", Proc. Electromotion '97, Cluj-Napoca, Romania, pp.82-87.

[5] Sobhy Serry Dessouky, Mahmoud Fawzi, Basem El Elnaghi, Hamed A Ibrahim, "Synthetic Loading of Three Phase Induction Machine Using PWM Inverter", Nineteenth International Middle East Power System Conference (MEPCON), Menoufia University, Egypt, 19.21 December 2017.

[6] P. Lasage, M. Alacula, L Gertmar, "Dynamic Thermal Loading of an ivnerter fed Induction Machine", IEEE/kth Stocckholm PowerTech. Conference, 1995, pp.241-244.

[7] Emmanuel Agamloh, Andrea Cavagnino, Silvio Vaschetto, "Applicability of Superposition Equivalent Loading Method for Induction Machine Temperature Test", IECON 2019 – 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, USA, 21-23 Oct.2018.

[8] I. Boldea, L. Tutelea, C. Klumpner, "Artificial loading of Induction Machines: A review", Workshop on ELECTRICAL MACHINES' PARAMETERS, Thechnical Unioversity of Cluj-Napoca, 26th of May 2001.

[9] C. Klumpner, I. Boldea, F. Blaabjerg, "Artificial loading of the induction motor using a matrix converter", Proceedings of PEMD London 2000, pp.40-45.

[10] Abdelaziz Y. M. Abbas, John E. Fletcher, "The Syntethic Loading Technique Applied to the PM Synchronous Machine", IEEE Transaction on Energy Conversion, Vol. 26, No. 1, March 2011.

[11] Ke Li, Yi Wang, "DC-Link Voltage Fluctuation Reduction of Vector Controlled PMSM Drives with Reduced DC-Link Capacitor", 2018 IEEE 4th Information Technology and Mechatronics Engineering Conference (ITOEC), 14-16 Dec. 2018, Chongqing, China.

[12] A.D. Martin, L. Tutelea, R. Babau, I. Boldea, "A novel approach to PLCs based system utilized in electric drives", 2019 International Aegean Conference on Electrical Machines and Power Electronics (ACEMP) & 2019 International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), 27-29 Aug. 2019, Istanbul, Turkey.

VIII. Biographies

Ion Boldea IEEE Life Fellow, worked and published extensively (250 papers, 3500+ citation, H index: 36 in Web of Science) in linear and rotary electric machines, drives and MAGLEVs. He was published numerous books, with 6000 entrances in libraries worldwide ("WorldCat.com"); 2015 IEEE Nikola Tesla Award.

Lucian Nicolae Tutelea (M'07) received the B.E. and Ph.D. degrees in electrical engineering from the University Politehnica of Timisoara, Timisoara, Romania, in 1989 and 1997, respectively. He is currently a Professor at the University Politehnica Timisoara in the Department of Electric Drives and Power Electronics. He was a Visiting Researcher at the Institute of Energy Technology Aalborg University, Denmark (1997, 1999, 2000 and 2006); and at the Department of Electrical Engineering, from Hanyang University from Seoul, Korea (2004). Also, he has cooperation with industry: ABB research Center Sweden, Vestas Denmark, Embraco, Brazil, and Hyosung South Korea. His main research interests include design, modeling and control of electric machines and drives.

Adrian Daniel Martin Received the B.E. degrees in electrical engineering from the University Politehnica of Timisoara, Timisoara, Romania, in 2017. Currently he is a Teacher Assistant and a PhD. Student at University Politehnica Timisoara in Electrical Engineering Department. Since 2015 he achieved experience in industrial automation sector. His research interest include motor control techniques, active vibration damping in reciprocating compressors driven by induction motors and PLC programing