Asynchronous Motors Drive Systems Command with Digital Signal Processor

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Abstract—The objectives of this paper consists in developing methods and technologies of command and protection of performant static power converters for the drive systems, which meet the quality of electricity requirements, using intelligent algorithms, performance computing system and DSP platforms.

Keywords—Asynchronous motors, Command, Digital signal processor.

I. INTRODUCTION

The definition and classification of concepts related to power electronic equipment have been made by the IEC (International Electrotechnical Commission) [1]. The nomenclature for such equipment is "Power electronic converters" or shortly, "Static converters". Static converters are made up of semiconductor devices (static switches) and ancillary components (coils, transformers, capacitors, etc..), used to modify one or more characteristics of the electric power supply system. Over 70% of world electricity is transmitted through the static power converters [2]. Consequently, the energy optimization of existing structures and the development of others, are issues of current and future electrical and electronic engineering domains. The main components of markets of static converters and power semiconductor devices are: industrial processes, automotive, electrical transport (traction power), computers and peripherals, communications, electrical/electronic household appliances and energy. The static converters in industrial processes are used mainly in the following applications: industrial drives adjustable (hydraulic, pneumatic, electrical and combined), the command and control of processes in the field of chemical, metallurgical and nuclear. The electric drive systems area is very important.

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It is estimated that currently over 65% of the electricity produced is consumed in the drives in different areas by fans, pumps, compressors, machine tools, lifting equipment, robots (automated manufacturing lines), etc.

In the automotive industry the development and improvement of components continued by making drive systems, conventional and unconventional performance, new types of sensors, etc. which solves all the more acute requirements related to: road safety, economy, reliability, comfort and environmental protection.

The electric transmission systems that are based on electric traction is a necessity today, when it must be provided a quick and cheap transportation in urban and interurban traffic with passenger and goods [3].

The power converters in the field of computers and peripherals, are used in switching power sources and uninterruptible power sources (UPS).

The communications and semiconductor market power increased and the main factor of the growth of this market is represented by power semiconductor devices (MOSFETs and power diodes) for wireless telecommunications and portable personal communications [4]. [5].

The MOSFET transistors have the most spectacular increase due to extraordinary demand for equipment that allow the connecting to Internet. The electrical/electronics household appliances has diversified and has continuously developed to meet the needs and demands of people.

In the energy domain, the static converters are used to achieve supply equipment of high power electrical generators. The biggest static converters are installed in electrical networks station of transmission in high voltage direct current (over 140 kV) and high power (over 1 GW). In Europe, with their help, the elastic interconnection can be made between the power grid in the West with the East [6], [14].

II. CLASSIFICATION OF STATIC CONVERTERS

In Fig. 1 is shown the block diagram of a static converter. It is noted that to the entry there is electrical energy that has certain parameters (amplitude V_1, F_1 frequency, number of phases M_1) and which is processed by the converter resulting to the output electrical energy with modified parameters(V_2, f_2, m_2), the whole process taking place with a certain efficiency.

The development trends of static converters follow several main directions:

- the improvement and emergence of new power semiconductor elements completely ordered,
- the developing of new structures for static converters,
- the development of control strategies and related circuits.

The current and future development of power devices could be characterized as follows [16], [19]:
- the integration in the same capsule of the power device, logic control and protection circuits,
- the replacement of power transistors by IGBTs,
- the MOS transistor structure optimization for applications of high power and high frequency ,
- the replacement of thyristors and GTOs by MCTs in most applications power.

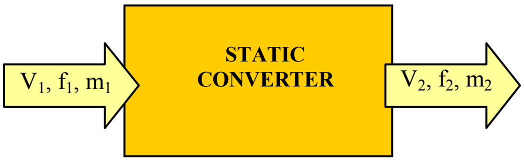

Fig 1. The block diagram of a static converter

III. ELECTRIC DRIVE SYSTEMS

The development of automation and robots in some important industries such as: machine building, metallurgy, transport, etc. was and is inextricably linked to the development, generalization and improvement of drive system and electric measurement as the most effective methode to obtain the necessary mechanical energy based on power conversion [8] ... [13]. The electric drives are currently the majority in relation to hydraulic and pneumatic ones because of:
- cvasigenerale availability of electricity ,
- the possibility of connecting straight to the source of energy ,
- electric motors robustness, allowing widely overloading of mechanical load,
- good dynamic performance (reduced response time between the time of command application and its execution),
- high energy efficiency (> 90%),
- high reliability, low cost, and reduced maintenance costs,
- the possibility of modifying speed widely,
- compatibility between command systems and electric motors.

A. The structure of an electric drive system. The block diagram of an electric drive system is shown in Fig.2.

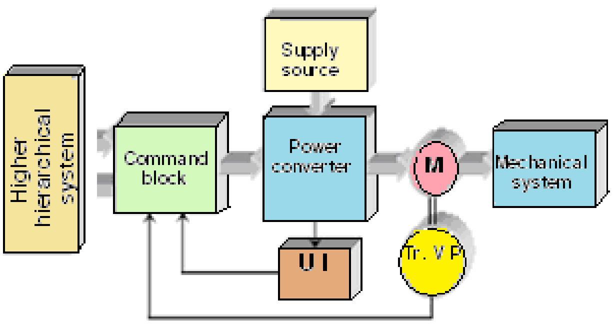

Fig. 2: The block diagram of an electric drive system.

The superior hierarchical system provides the command quantities based on requirements and status signals from the control equipment. The equipment control, analog or digital, take the prescribed quantities and signals generated by sensors (current and/or voltage) and transducers (speed and/or position) and, on this basis, commands the static power converter.

The command block of the power converter is an essential component of the drive system that performs the following functions:
- communicates continuously bilateral with the superior hierarchical system, it takes from it commands and the prescribed values of kinematics parameters that must adjusted (position, speed, power) and provides to it information on the current state of movement, the state of damage, etc.
- sets the current values of kinematics parameters based on information received from sensors and transducers,
- provides to static power converter, the commands necessary to cancel the misconduct of prescribed quantities and the current ones,
- ensures the command, supervision and protection of power converter.

The static power converter is a device consisting of power semiconductor elements. To the technique of adjustable electric drives the interest is mostly on the controlled static converters, which are composed of commanded semiconductor elements, and that, in addition to electric energy conversion, allow the command of average power transmitted to the electric charge.

To highlight the role of static power converters in a system of adjustable speed electric drive it is presented the balance of electricity consumption in electric drives, in which the difference between electricity consumed and useful mechanical energy represents the electrical and mechanical losses, which turns irreversibly into heat.

For the parameters of mechanical energy (torque, angular velocity) to be controlled by electricity (to eliminate mechanical losses), it is necessary that between motor and power supply to exist electricity metering devices by modifying its parameters (voltage, current, frequency), called electrical control so as to result in a decrease of mechanical losses.

The control of mechanical parameters in a mechanically way(mechanical control - Fig.3) with speed reduction gears or gear box is characterized by low productivity (due to high mechanical losses), low reliability, high cost and limited unit power due to construction considerations.

The AC motors (ACM) are the cheapest in the area of applications that require more than 375 W. The simple construction, high reliability and functional safety made ACM the preferred engines in industrial drives that require constant speed and in commercial and residential applications where there is easy access to the mains supply. Compared with DC motors, ACM has the following advantages [17], [18]:

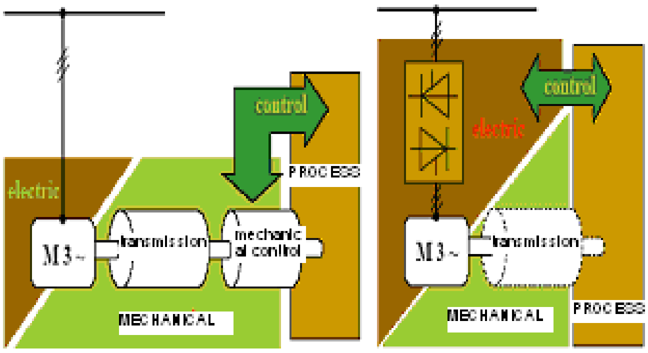

Fig.3. Reducing power losses in electrical drives by the shift from mechanical control (a) to power control (b).

- greater robustness and lower cost price, both because of manufacturing technology and smaller gauge to the same output power,
- higher reliability due to lack of brushes, collector and the possibility of using them in explosive atmospheres. These motors can operate, without having to even change the bearings, for more than 10 years if the technical specifications for use are respected.

The main disadvantage of ACM is the more difficult and more expensive speed control.

In the case of electrical drives, the mechanical energy required is obtained by converting electricity from grid-phase or three phase alternating voltage (power supply). The continue development of power electronic equipment powered by the same alternating voltage network, simultaneously with the power consumed by them and also with the use of computing in offices and homes has the effect of development in the power grid distribution of reagents non-sinusoidal currents. The recovered alternating current is equivalent to an amount of sinusoidal current with a fundamental component of basic frequency (50 Hz) and a series of harmonics, whose frequencies are multiples (generally odd) of the basic frequency (150, 250 , 350, 450, 550 ... Hz). The harmonic currents are injected in the three phase power supply system. Thanks to them, on the system impedances appear harmonic tensions that overlap fundamental voltage and distort the tension network system.

The more a process is complex, the more its management requires accurate knowledge of the parameters of physical quantities that characterizes him. In the case of an adjustable drive system, his driving is made without human intervention, based on information collected from process by sensors and transducers. They must provide information about the current and the supply voltage of the engine and the engine rotor speed or position. For measuring current it can be used: shunts, current transformers and current-tensions transducers. The shunts are usually used to measure high continuous currents contain(sometimes it is used in the AC too), using Ohm's law.

The measuring current transformers are used to convert primary current value to a value of secondary current of 1A or 5A, which are prescribed in standards. At the same time, the transformers make a separation between low or medium voltage circuit from the primary and the low voltage secondary circuit, ensuring operator safety personnel.

The current-voltage transducers belong to the category of modern unconventional devices for capturing current signals whose output signal is a voltage, having electronic processing circuits that carry the default current-voltage conversion. These modern sensors can be inductive or optical type and are characterized by: the linearity of transfer characteristic, very large dynamic range, extended; extended factor of rated primary current, satisfactory response time, high isolation voltage.

This category of current-voltage transducers includes: ring Rogowski current transducers, Hall effect current transducers, electro-optical sensors current transducers.

Ring Rogowski current transducers are made up of a wound, uniformly distributed around the conductor crossed by the current that we want to be measured.

The Hall effect consists in the emergence of a transverse electric field (known as electric field Hall-EH) and a potential difference in a metal or semiconductor traveled by an electric current when they are placed in a magnetic field perpendicular to current direction. This effect has opened the design view of current sensors, produced and marketed by swiss company LEM, which conducted a wide range of current transducers galvanically isolated. They are divided into: Hall effect transducers with open loop and closed loop. The closed loop current transducers are characterized by excellent accuracy, good linearity, low deviation with temperature, low response time, broadband frequency, not introducing losses in the measuring circuit and exceeds current bear without damage. This series of transducers includes the following: LTS 6-NP, LTS 25 LTS 15-NP and-NP.

The current transducers with electro-optical sensors based on electro-optical effects tend to develop, without doubt, the same as other types of sensors. Optical sensors are typically used in static converters supplied with high voltage for galvanic isolation and cover relatively large distances between the high voltage line measurement and ground. The voltage transducers are used to measure output voltage of static converters (from the terminals of electrical charge), for chargers or DC-DC converters or for voltage measurement from the intermediate circuit, for inverters. Construction and operating principle are similar to the current transducers.

The speed or turation transducer will provide information about engine speed in a drive system application. Usually it is used a tachogenerator to provide the necessary speed information. Since this transducer provides an analog voltage at its output, proportional to engine speed, it will be necessary to use an analog-digital converter to obtain the numerical value of this signal, which can be used in a digital system.

The position transducer makes the measurement of the system drive position (mounted on the engine and/or on the charge). Usually, a solution which provides an advantageous ratio of price/performance is offered by using incremental optical encoder transducer type. Encoder consists of the following main components: transmitters (LEDs), receiver (photodetectors), rotational encoded disk, hard disk (mask) and the electronic circuit of signal processing.

The encoders provide 2 rectangular pulse trains, offset to 90^0 each other to achieve reversing and another digital signal, so-called zero signal of the encoder. This signal becomes active only once a rotation and can be used to initialize the scheme after placing under voltage, to properly set the absolute position of an information system.

IV. ASYNCHRONOUS MOTORS DRIVE SYSTEMS

Due to construction and operating advantages which they present over other motors, in the recent past years have many researches on adjusting their speed have been made. Some methods, become classics, are applied in many industrial installations and others, based on power electronics, are being extended as it ensures quality indices comparable with those of DC drives. Starting from the expression of asynchronous motor speed:

$$n = n_0(1-s) = \frac{60 \times f}{p}(1-s) \qquad (1)$$

we can observe that the speed can change by the sliding s, the power frequency f and number of pole pairs p.

A. Adjusting the Speed by Modifying the Voltage Frequency. The adjust of speed by modifying the frequency of supply voltage remains the most efficient method of adjustment. The adjustment range is very large, the yield good and the mechanical characteristics are rigid. Realization of changing frequency involves supplying engine from variable frequency power sources, which may include: converters with rotating electric machines or static frequency converters. If it is considered that the supply voltage U_1=ct, than to lower frequencies from the nominal, $f<f_n$, the resulting flow increases causing the saturation of the machine. Therefore, for speeds lower than nominal value, both voltage and frequency are modified, maintaining constant the report U_1/f [11]. That means that the flow $\Phi = \frac{1}{K_1} \times \frac{U_1}{f}$ remaind constant. If the ratio of amplitude and frequency of the supply voltage is constant then magnetization remaind also constant throughout the engine operating range. Recent developments in microcontroller technology, allow engines to be controlled more effectively and at a lower cost compared with past decades. This will accelerate the transition from electromechanical to electronic control in some market segments, enabling the implementation of command circuits and speed control (variable) engine to optimize engine operation in other domains and the possibility to provide a cost reduction in a component level in all market segments. The LSI integrated circuit Hef 4752V is used to control asynchronous motors inverters, basing on PWM principle. The circuit summarizes three signals out of phase by 120°, to which the average varies sinusoidal in time on a scale from 0 to 200 Hz frequency. Using MOS technology with local oscillation complementary (LOCMOS) is mounted in standard 28-pin dual in-line capsule [12].

B. The Adjustment of Speed Using Systems Target Field. The asynchronous motor is the cheapest engine, but more difficult to control. This limitation of control is mainly due to nonlinear dependence that exists between the torque developed by the asynchronous motor and the currents absorbed from the grid, dependence which hampers control of a drive with such a motor in a transitional regime [15]. The solution most frequently used to overcome this inconvenience is the system of regulating target field, called also adjustment vector or control vector, in English using the names: FOC (Field Oriented Control) UFO (Universal Field Oriented) or Vector control. The principle of targeting field of AC cars is to separate the dignitaries that produces the electromagnetique torque from the ones which produce flows of magnetization. By this method of regulating the asynchronous machine is controlled like a DC machine in which the electromagnetic torque is given by the scalar product of flow excitation and the current from induced, quantities which are independent.

C. Two-phase Mathematical Model of the Car. The system of equations describing the relationship between electrical quantities characteristic to the machine, the developed electromagnetic torque and the connection with the mechanical quantities represents the mathematical model of asynchronous motor. The models with concentrated parameters are divided into two basic categories: models in phase coordinates and models using orthogonal axes. Starting from the notation: p – the number of pairs of poles, θ_m - mechanical angle, $\theta=p\cdot\theta_m$ - electrical angle, $\alpha=p\cdot\theta_m+2\pi/3$, $\beta=p\cdot\theta_m+4\pi/3$, $\omega= d\theta/dt$ - rate of electrical rotation of the rotor, C_{em} electromagnetic torque R_S, L_S, R_R, L_R - characteristic parameters of the three stator windings, rotor respectively. Since there are different windings, the resistors RS, RR and their reactance's flaws are different, while their mutual inductance is the same, then the original model of asynchronous machine with squirrel-cage will be [7]:

$$[U]= [R]\bullet[I] + [L]\bullet \frac{d}{dt}[I] + \omega\bullet \frac{d}{dt}[L]\bullet[I]$$
$$C_{em}= \frac{p}{2}\bullet[I]^t \bullet \frac{d}{dt}[L]\bullet[I] \qquad (2)$$

The three phase quantities (voltages, currents and flows) are reduced to a plan vector called spatial phaser witch allows a compact writing of state equations. The phaser characterizes the whole three phase of the system, as follows:

- indicates the time variation of quantities and phase shift,
- indicates phase shift in space occurred due to the phase windings layouts in terms of constructive. In the following it will be considered the case of stator currents for witch the instantaneous values on the axes a, b and c are i_a, i_b, i_c.

The spatial phaser shown in Fig.4 describes the set $(\overline{i_a}, \overline{i_b}, \overline{i_c})$ and is given by:

$$\overline{i_s} = \mathrm{k} \bullet (i_a + \overline{\alpha} \bullet i_b + \overline{\alpha}^2 \bullet i_c), \tag{3}$$

where $\overline{\alpha} = e^{j2\pi/3}$ and $\overline{\alpha} = e^{j4\pi/3}$ are operators of spatial rotation.

Most authors take for *k* the appreciation of 2/3. This choice (uncritical) is justified by a reverse transformation of magnetic voltage of a three phase system that adequate value from a phase ($1/{3/2}$ =2/3).

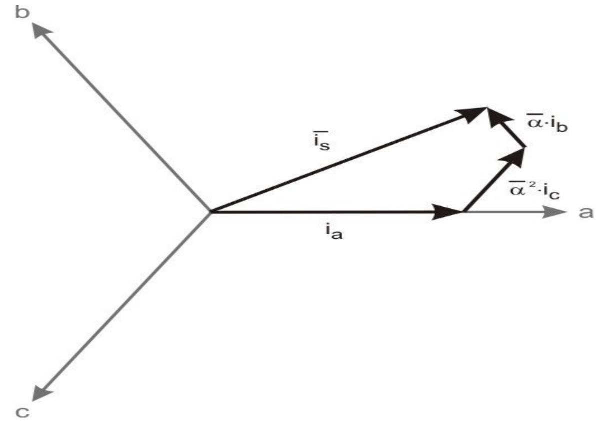

Fig. 4: The diagram of spatial phaser for the stator current.

The vector product of any two of the three components (i_{Sd}, i_{Sq}, i_0) is zero. To convert the variable three phase system into a invariable two-phase system (as the current engine) we make the transformations: Clarke, Park, Park and Clarke reverse.

Clark's transformation. Makes the transformation of the system *(a, b, c)* into the *(α,β)*. We start from a balanced three phase system which we transform using Clarke transformation into a balanced 2-phase, which is a system of rotation in 2 phases (α, β) that spins at the speed of rotation of the magnetic field of the stator (ω_S). The guideline of the new system (α, β) is chosen so that α have the same direction as *a*. By reporting the spatial phaser $\overline{i_s}$ to the reference system with two axes (α, β) we obtain the components:

$$\begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \\ i_0 \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & \frac{1}{3} \\ 0 & \frac{2}{\sqrt{3}} & -\frac{2}{\sqrt{3}} \\ \frac{2}{3} & \frac{2}{3} & \frac{2}{3} \end{bmatrix} * \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{4}$$

For the symmetrical and balanced three phase systems, the homopolar component i_0 of the system is zero (or negligible), and the transformation becomes:

$$\begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{1}{\sqrt{3}} & \frac{2}{\sqrt{3}} \end{bmatrix} * \begin{bmatrix} i_a \\ i_b \end{bmatrix} \tag{5}$$

The Park's transformation. It makes the transformation of the system (α, β) into the system (*d, q*). This transformation makes the passage from the system axes (α, β) relative to the stator to a rotating orthogonal system (*d, q*). The axis d is chosen in the same direction as the flow runner and q gives the size of the machine torque. This transformation is characterized by*:*

$$\begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} * \begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} \tag{6}$$

D. The Requirements of a Vector Control System. A vector control structure to control the torque of asynchronous machines must meet the following essential functions:

- a transformation of reference system (*a, b, c*) into the system *(d, q),*
- determining a position of the flow Φr,
- to generate commands to control the flow and torque, which, based on their references will define the references of the transformed currents,
- to activate the control of the transformed currents to ensure following up these references,
- a transformation that provides the change of the reference system (*d, q*) into the (*a, b, c*), allowing operation of electrical quantities by means of a static converter, in this case a PWM voltage inverter. The reverse transformation for obtaining reference quantities necessary to control the elements from the power circuit is characterized by relations of transition from two phase to three phase system:

Park reverse:
$$\begin{bmatrix} v_{s\alpha} \\ v_{s\beta} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \cdot \begin{bmatrix} v_{sd} \\ v_{sq} \end{bmatrix} \tag{7}$$

Clarke reverse:
$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{3} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} v_{s\alpha} \\ v_{s\beta} \end{bmatrix} \tag{8}$$

The vector adjustment is called indirect if the adjustment system doesn't receive information about the stream. The control block will calculate the position of this vector. Through the direct method, the flow is measured directly using flow transducers (Hall probes) mounted inside the machine that provides direct the spatial phaser's amplitude and position of the flow. The structure of vector adjustments systems depends also on the flow to which adjustment is made. Therefore we can say that there are:

- systems regulating targeting the flow runner to which the axis d^r of the synchronous reference system is oriented to spatial phaser of the flow runner
- systems regulating targeting the stator flow to which the axis d^s of the synchronous reference system is oriented to spatial phaser of the stator flow
- systems regulating targeting the flow of

magnetization to which the axis d^m of the synchronous reference system is oriented to spatial phaser of the flow of magnetization.

The systems targeting the runner flow are the most often used in electric drives with asynchronous motors because of the loop control simplicity and the calculation of the control quantities. This vectorial adjustment system is the most common used.

The systems targeting the stator flow are less used because of the complexity of the circuit design flow and the difficulty of the much distorted stator voltages measurement for PWM inverters, although the stator voltage equations and the decoupling circuit are simpler than for systems based on targeting the flow rotor. A guidance system after the flow of magnetization has the same degree of complexity in terms of block implementation of the flow model with a system targeting the stator flux.

V. THE CONTROL WITH DSP

The implementation of the vector adjustment system with AC motors requires a substantial computing effort; while sampling periods which maintain the control in real time can not exceed 200-300 μs.

A. Digital Signal Processors. Digital Signal Processors (DSP) are microprocessors whose architecture has been optimized for real time processing of discrete signals obtained from sampling of continuous quantities. Their architecture has been designed to minimize the period of implementation of processing algorithms, such as: screening of a signal; convolution and correlation of two signals; correction, amplification and signal processing, fast Fourier transform (FFT). It is widely recognized that DSP processors offers one of the best combination of integration, flexibility, efficiency and performance. The drive systems are becoming more and more complex and, accordingly, the complexity of control increases (target field or forming current type with switched reluctance or artificial intelligence), and so the design of such systems becomes a difficult task in absence of efficient controllers so that can be, in turn, designed in a friendly environment development. The TMS320F2812 processors are designed for controlling electric motors, but they can be regarded as general purpose processors as they can be used for other applications.

B. Electric Drive System. In Fig.5 is presented the electric drive system. The input Filter includes hardware protection, EMI filter and optionally a block correction of power factor (PFC), which can be controlled through exits from DSP TMS 320 F 2812, produced by the company Texas Instruments. The correction circuit of CFA supplier factor may contain a battery of capacitors required for smoothing the continuous voltage from the charger's exit and a brake circuit that eliminates the energy stored in the engine. As noted, the scheme is based on measurement of two phase currents and motor speed. Measured phase currents, i_a and i_b, are used to calculate the "Flow model" engine equivalent (Fig.6), which is also based on information provided by the encoder speed, calculation done by DSP processor. Using DSP and vector control for electric drive system with asynchronous motor has the following advantages: high capacity torque at low speeds, good dynamic behaviour, and high efficiency in a broad range of speed, short time overload capacity, possibility of operating in four quadrants. The command of this drive system is operated using vector regulation known as "indirect vector control after flow runner", described above. Compared to the classical scheme it adds an additional block "field weakening" necessary for flow control engine. To increase speed, we increase the frequency of inverter control, and thus the supply voltage of the engine up to a maximum value (nominal value), corresponding to nominal speed, while maintaining constant flow engine [9]. In normal conditions flow is maintained constant but increasing speed over the nominal value is due to weakening (lower) flow. In this application we use a three phase motor with star connected stator coils and rotor cage. The parameters of this motor are: rated power 0.5 kW, rated voltage on phase 220V, rated current of 1.2 A, synchronization speed of 1,500 rpm, the number of pole pairs is p=2, the slip is 0.066, the moment of inertia of the rotor is $0.95*10^{-3}$ kgm^2, winding resistance is $0.95*10^{-3}$ kgm^2, stator windings resistance is 34.8 Ω and the nominal torque

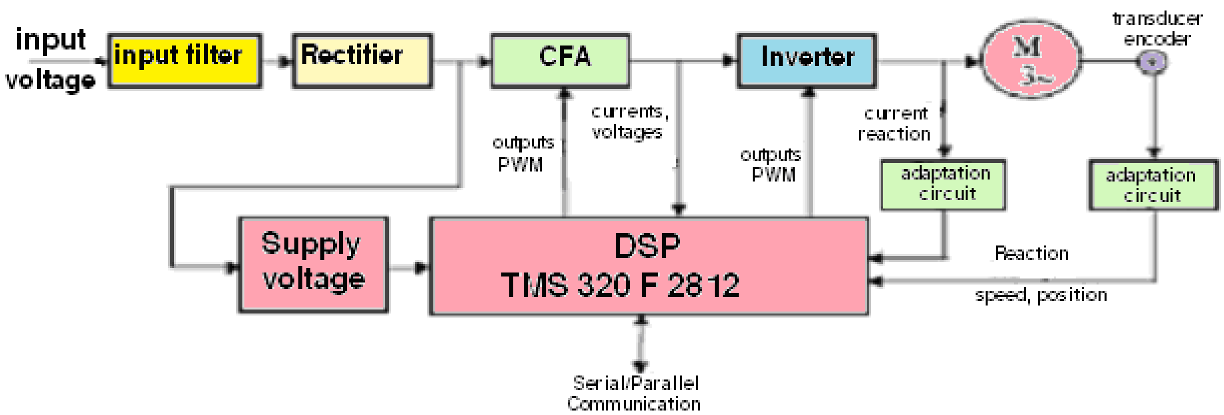

Fig. 5:The block diagram of an electric drive system with DSP and AC engine.

$$M_{nom} = \frac{P_{nom}}{\omega_{nom}} = \frac{500}{\left(\frac{2\pi \times 1400}{60}\right)} = 3{,}41Nm \qquad (9)$$

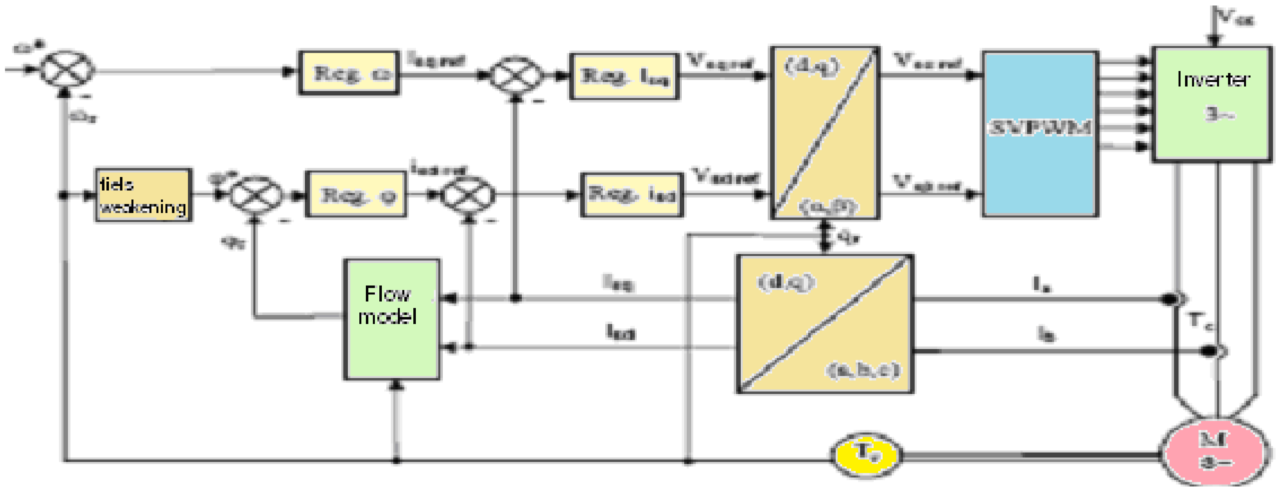

Fig. 6: The block diagram of the advanced vectorial control of an asynchronous engine.

C. Electric Power Circuit. The revolutionary development of electronic systems and power semiconductors in recent years has triggered also the development of new power semiconductor devices (modules with power transistors, IGBT transistors, other high performance devices with isolated grid, hybrid systems, intelligent modules). The intelligent power modules for industrial engines incorporate the power floor with an integrated control board in a package that has the same area of silicon. They allow designers to achieve the highest levels of energy efficiency, compactness and low EMI interference. Due to its high level of integration, these modules greatly simplifies design, reduces time to market and total cost launch system where they are used. Compared to discrete approaches, these highly integrated modules provide not only a great economy of space, but also eliminate time-consuming tasks for testing numerous discrete components. For this application we used the intelligent power module PM15RSH120 produced by Mitsubishi, one of the best known in this field worldwide. This module includes: the complete power circuit (6 IGBT transistors of an IGBT inverter and additional IGBT transistor for braking), forming and control impulse circuits of each transistor, logic circuits protection (short-circuit, overload, low voltage and at high temperature). He has the following parameters: rated current 15A, maximum continuous power voltage 1200V, maximum command frequency 20 kHz, the lock time delay (dead time) is 2.5 μs minimum. DSP sums the state of logic circuit of protection. Enabling protection, when one of the situations described above occurs, determine the absorption of a current (10-15 mA) by the F_O model inputs and forces to start the conduction of electroluminescent diodes of optocouplers.

D. Measurement Circuit and Current Adjustment. The vector control structure requires the current measurement on two phases of the engine. They have been used to measure current two LEM transducers because of their advantages and have been listed before. From the LEM transducers range was chosen the type LTS 6-NP which can be configured to measure a nominal value of 2 A for the primary current, a value close to the rated current of the motor, ensuring a good accuracy of measurement. The operation of these current transducers and their transfer characteristic were presented in chapter two, along with a circuit adaptation for a analogue digital converter with a range of entry variation 0-3 V. Since DSP processors TMS 320 F 2812 are equipped with analogue digital 12 - bit converter, where entry can change in a range of 0-3 V, the circuit adjustment is the same as described above. The digital analogue converter will provide a value $x=n(V_{ref}/4096)=n(3/4096)$, where n is the number of quanta. It means that adjustment circuit to provide the output signal equal to: 0V to a measure current $-I_{max}$, 1.5 V for a measure current null and 3V for a measure current I_{max}. Current value through a phase of engine will be:

$$I=[I_{max}/(V_{ref}/2)](x-1{,}5)=[I_{max}/(3/2)](x-1{,}5) \qquad (10)$$

For this application we select I_{max}=2A, being an aprons value for nominal current

$$\sqrt{2}\ I_n=1.41*1{,}2A=1{,}692A$$

E. The Circuit for Speed Measuring. To measure the engine speed we use a bi-directional incremental encoder with N = 1000 pulses / rotation. The encoder provides the signals A, B, I (or Z) and possibly their complementary signals. Using signals A and B we determine the direction of rotation of the engine, and signal I switch to a full rotation. The speed calculation is made taking into account that the maximum number of pulses counted for one full rotation is 4xN, because for the detection of the direction of rotation, it is necessary to follow the sequence of values of the channels A and B: 00, 01, 10, 11, which may be used also for multiplying pulse. In the same time with the start of counting (metering) pulses N_C from the transducer, the timer also is activated and so the time Δt corresponding to them to be known (pulses N_C). After one full rotation the signal Index/Zero is activated and will reset the two timers and pulse counting N_C. Thus, the speed, expressed in revolutions per minute, will be determined with the following relationship:

$$n = \frac{N_C}{4 \times N} \times \frac{60}{\Delta t} = \frac{N_C}{4000} \times \frac{60}{\Delta t} \quad (11)$$

The encoder connecting to the DSP is made by linking signals A, B, I/Z to internal interface specialised QEP (Quadrature Encoder Pulse Kingdom). If the encoder supply voltage is different from the supply voltage of DSP it must be used an adaptation circuit of signals. In Fig.7 is presented a circuit containing logic gates with the hollow collector which adapts TTL voltage levels (5V) of the encoder with 3V levels of DSP.

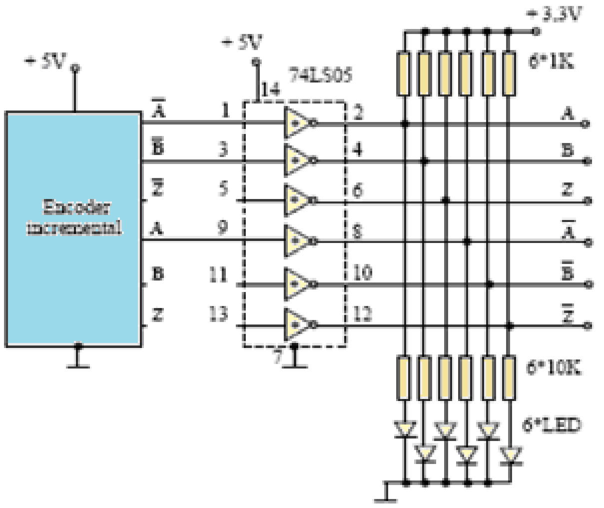

Fig. 7: The proposed circuit for adaptation of incremental encoder signals to DSP.

F. The System with DSP TMS 320 F 2812.* The TMS320 signal processor family provides a very valuable software support, both through proper environmental facilities and programs of libraries that makes available to users. The DSP F281x generation is a member of TMS320 family produced by Texas Instruments. The F2812 processor is an engine C/C++ very efficiently, allowing users to develop, in addition to control system applications the complex mathematical algorithms. F2812 contains a pipeline protected by 8 levels deep with access to memory. This system allows the execution of applications at high speeds without requiring expensive memory. TMS320F2812 processors are designed for controlling electric motors, but they can be regarded as general purpose processors that can be used for other applications too. As shown, DSP processor is dedicated for the management of systems drive representing the core around which the platform TMS 320 F 2812* has been developed, where it notes that you can connect multiple analogue and digital inputs and also digital outputs and PWM outputs specialized, the number of entries or exits being enough to be used in vector control of an asynchronous motor or any industrial process with few variable input/output. The development Platform TMS 320 F 2812* has 8 analogue input channels (enough to measure, for example, the 3 phase currents and continuous voltage and the current of the intermediate circuit, in the case of an inverter control), 8 digital input channels (which includes the specialized inputs where the encoder is connected) and 12 digital output channels (of which 6 outputs PWM). The digital inputs and outputs are connected through some intermediate circuits (buffers) of high speed 74 AC 573.

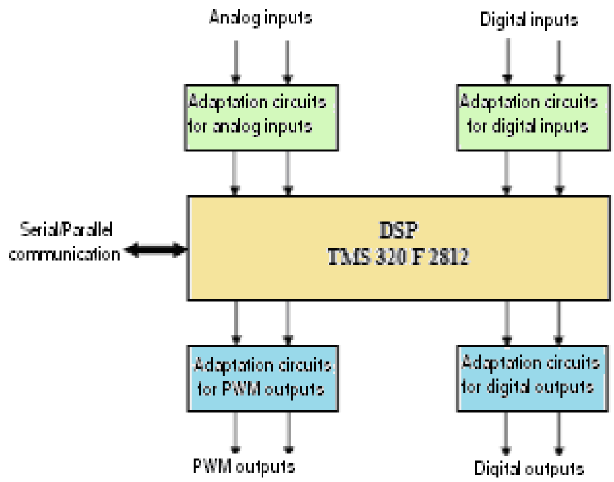

Fig. 8: Block diagram of the development platform TMS 320 F 2812*.

By using circuits switches, digital inputs can be simulated by disconnecting the input of the process with a proper positioning of a rider. Status output can be viewed by specific LED lighting. The analogue inputs are connected via operational amplifiers OPA 2340, in the repeater configuration of power, with the following characteristics: frequency band of 5.5 MHz, 150 µV offset voltage, output rate of variation of 6 V/µs. The simulation of analogue input was achieved by mounting of potentiometers and proper positioning of riders. To reduce wiring loops of mass the development platform we have made double-clad, one side (TOP) is mass in the area where the analogue circuits are placed and the other side (BOT) was used for connecting routes. With the practice we have obtained, corresponding to Figure 8, electric drive system with DSP and AC engine as in Fig. 9. The system components have a structure that differs more or less than the conventional.

So:

- the circuit strength achieved with intelligent power module includes both the control and protection. A very high current trend in the development of intelligent power modules and electrical drives is the incorporation of intelligence in the electric motor, by creating so-called intelligent engine which has included all the control

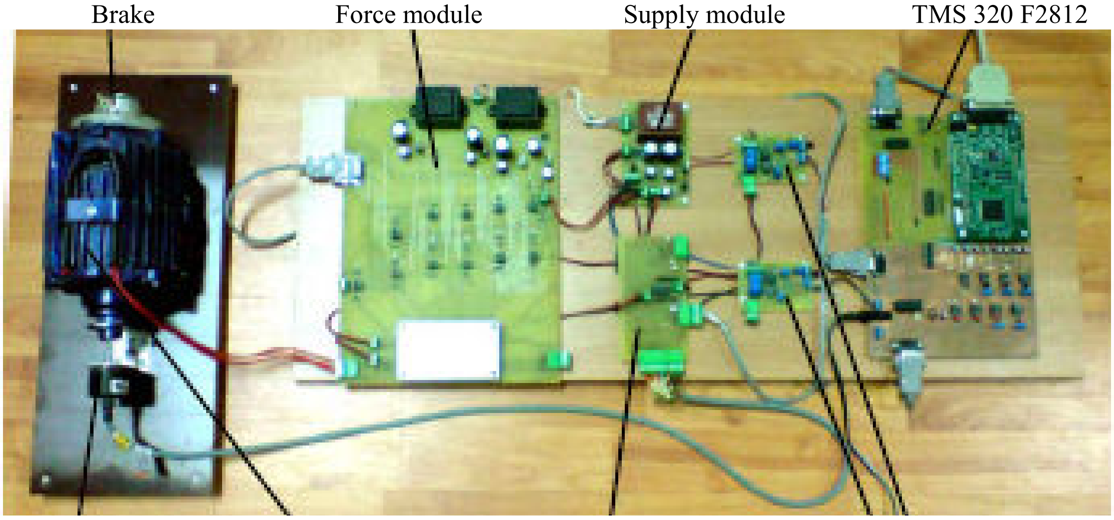

Fig. 10: Realization of electric drive system with DSP and AC engine [3].

microprocessor or DSP. The compact solution is well suited to multi-axis applications where each axis smart, connected in a network, can be controlled with high accuracy for any type of movement;

- the current measuring and adjusting circuit allows the current measurement through engine phases with current transducers with Hall effect due to their advantages: excellent accuracy, high linearity, low temperature derive, reduced response time, wide broadband frequency, doesn't introduce losses in the measuring circuit current and supports exceeded bear without damage;
- the measurement of speed is made with an incremental encoder with 1000 pulses/rotation, the level adaptation of signals we developed with high speed gates;
- the TMS320F2812 DSP development system is comprised from circuit adaptation for input/output digital/analogue, buttons to simulate the functions Start/Stop and to simulate digital inputs, potentiometers to simulate analogue input and output and Led's for output viewing.

VI. CONCLUSIONS

In conclusion, the using of the TMS320F2812* development system with the TMS320F2812 digital signal processor in digital control and the speed regulation of electric motors has proved very effective, reducing the work required for classical regulation.

Working with it is not very difficult because the tools and software modules that can be used in programming, minimizes the work of the design engineers of the adjustment system, allowing it both theoretical verification, off-line implementation, and verification in real time too. F2812 has all the peripherals necessary for simultaneous control of two alternative three phase motors

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