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Energy Demand Management Motor Control Using Multilevel Inverter

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Abstract: The main aim of this project is to explain the unbalance electric scenario in the Power System. This project will explain how unbalance condition is one of the most important problems associated with power quality and creates several disturbances to the Power System. It includes the Harmonic reduction techniques to improve the power quality and it also includes the simulation for the same. This project presents a multilevel inverter topology suitable for the generation of 3 phase supply. A simple and fast carrier based Direct-torque control with pulse width modulation (PWM) scheme is also proposed for the topology which utilizes only the sampled amplitudes of the reference wave for the PWM timing computation. Individual independent inverter is combined to form the three phase output. Because of this the loads are not specific and it can be varied.

Key words: Multilevel-inverter · PWM techniques · MSP 430 controller · Induction motor · V&I balanced condition

INTRODUCTION

Objective of the Project: The concept of demand-side management (DSM) has been introduced in the USA more specifically in the electricity industry in the mid-eighties [1]. It has been originally defined as the planning, implementation and monitoring of a set of programs and actions carried out by electric utilities to influence energy demand in order to modify electric load curves in a way which is advantageous to the utilities [1]. Changes in load curves must decrease electric systems running costs both production and delivery costs and also allow for deferring or even avoiding some investments in supply-side capacity expansion. Thus,DSM has been driven by strict economic reasons. Energy efficiency was a privileged instrument for DSM implementation as will be seen Hence, in societal terms this was a typical win-win situation as consumers would also benefit from cheaper energy services as overall efficiency would increase [2].

DSM has been a major breakthrough that led to a great deal of innovation both at business management and at technological development and also to huge environmental benefits. Yet, a great number of DSM tools already existed previously to the concept and had been in use by many utilities namely those tools related to remote load control known as load management (LM) [3]. But LM aims predominantly at influencing power use the amount of energy used by unit of time at specific times.

Energy efficiency was actually a new comer to the business brought by DSM to the portfolio of utility management options. There are six main objectives defined in the context of DSM, known as: peak clipping, valley filling, load shifting, flexible load curve strategic conservation and strategic load growth[4]. Apart from strategic load growth (SLG), all other options require that the utility's system is under pressure and requires either capacity expansion or load relief[5]. Cost-benefit analysis will dictate which options to adopt In general, DSM implementation options may be classified into several different broad categories customer education, direct customer contact, trade co-operation advertising promotion, alternative pricing, direct incentives. Some measures pin-pointed in the text below are examples of some of them [6].

Problems Facing Utility-Driven Dsm: Influencing the way electric energy is used has become an effective means of complementing supply-side options with the purpose of increasing overall systems efficiency. Determining the appropriate mix of supply-side and

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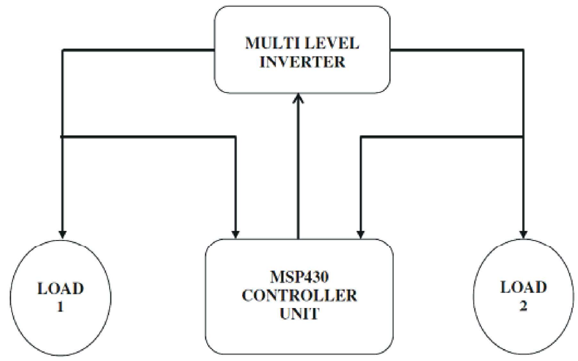
demand-side resources became the goal of the so-called integrated resource planning (IRP), allegedly leading to a global least-cost approach [7]. Several difficulties had to be tackled with to solve the problem of cost-benefit evaluation of demand-side options. A standard approach has been designed for the purpose which has only recently been adapted to the European specificities through an initiative of the European Commission in 1996.

DSM has been recognized as an ally to environment conservation as it leads normally to lower overall consumption growth and contributes to using available resources in a more rational way the portfolio of DSM even includes fuel replacement options [8]. Huge savings, both financial, energy and environmental have been claimed, namely in the USA as due to the massive adoption of DSM programs by utilities, bounded by strict regulatory constraints. The trend towards highly regulated DSM and IRP in the USA actually forcing utilities to adopt certain decisions though with the guarantee of financial compensation shows in itself that these instruments have been considered of high societal value. DSM has been identified since the infancy of the concept as a privileged tool for utilities to contribute to the societal goal of environment protection besides being profitable on its own in many cases. In view of this advantage in some countries regulations have been issued and accompanying procedures implemented that sought to maintain economic advantage for the utilities while promoting energy efficiency on the demand side. Losses of revenues had to be compensated in some way which is not possible in strict economic terms, in a competitive environment.

DSM Opportunities: Experience shows that in countries where liberalization is more advanced, utilities show a natural tendency towards maximizing profits and hence to promote energy sales. This is clearly at odds with energy efficiency promotion and led to the abandonment or in the best cases to a strong decrease of DSM utility-driven initiatives. A broader content has been proposed above for DSM which enlarges the list of actors with an active potential role in the promotion of energy efficiency authorities, utilities, consumers, energy service companies, equipment manufacturers. Though traditionally utilities play a major role in DSM, the initiatives of local, regional or national authorities in general will have to be intensified.

Nevertheless, regulation will have to be adapted to the prevailing market conditions at every moment in the future. It is definitely different to issue regulations in conditions of franchise market to some energy types of supply or to do it when suppliers of the same energy form compete with each other for customers. Namely, energy price is strongly influenced by the form of market organization. Hence, a good regulation today may become obsolete tomorrow and accrued difficulties may arise. When such faults take place, protective devices are used in order to clear the fault.



1. Block diagram

The block diagram shown above displays the controller part, loads and inverter section of the system. The inverter is controlled by the msp430 microcontroller based on the feedback received from the loads connected to the inverter. The input signal for the invertor from the controller part will be varied based on the position of the load applied to the system. When normal load is applied (i.e. only one load is working) a normal pwm signal with fixed frequency level will be applied to the invertor which will generate the voltage that is sufficient to drive the single load when the load has been increased by adding one more load to the system the frequency of the pwm.

Generated from controller is increased to satisfy the power constrain in order to satisfy the demand side management the frequency has been changed the demand created as been satisfied The feedback from the load will be collected by the controller in order to maintain the demand side management in the system we created in both balanced and unbalanced criteria.

Multilevel Inverter: Multi-level Inverters are a type of inverters whose construction is similar to the single and three phase inverters as explained earlier [9]. The Figure 2 shows a multi-level inverter which is an extension of single and three phase inverters. Here four IGBT circuits are connected in three different legs and the diodes are connected in parallel to each leg in opposite direction. Also, the loads are connected between two IGBT circuits for each leg.

MSP430 Control Unit: The MSP430 is perfect for low-power and super miniature projects. Not only are smaller circuit boards cheaper to make, but they are desirable in many applications; such as in wireless sensor nodes, wearable electronics and others. Standard 0.1" headers are simply too big for very small boards. To reduce the size requirement for the programming header, I have started using 0.05" headers. With this post, I would like to share how I use smaller headers to easily make my projects smaller and more cost efficient. Due to how cheap the MSP430 Launch Pad is, it is often the best way to program your custom MSP430 boards. One of my earlier posts details how I using a 6 pin 0.1" header. It is important to me that I include both the UART RXD and TXD pins in the programming header for debugging purposes. The simple schematic is shown above. Using a 3x2 pin 0.05" header on the target board, I created a "converter" board which connects to the Launch Pad using a 6 pin 0.1" header. Additionally, if I want to reduce the footprint further, I can use only a single 3x1 pin 0.05" header, ignoring the VCC, RXD and TXD pins (as long as the target device is self powered). The circuit board is shown above. It is very simple, yet very effective [10]. The overall footprint of the programming header has been reduced significantly. Some possible improvements include the addition of a switch to allow you to choose if the device will be powered by the programmer or not, a protection diode for VCC and a reset push button for those devices which are too small to have one. If you use the Eagle file provided below to make your own, please keep the URL to my blogs on the silkscreen [11].

Induction Motor: An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation [12], separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type [13]. Three-phase squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives(VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications [14]. Squirrel cage induction motors are very widely used in both fixed-speed and VFD applications.

Direct Torque Control (DTC): Direct torque control was developed by Takahashi and Depanbrock as an alternative to field-oriented control DTC is a control philosophy exploiting the torque and flux producing capabilities of ac machines when fed by a simple voltage source inverter that does not require current regulation loops, still attaining similar performance to that obtained from a vector control drive. In a direct torque controlled (DTC) induction motor drive supplied by a voltage source inverter [15], it is possible to control directly the stator flux linkage _s (or the rotor flux _r or the magnetizing flux _m) and the electromagnetic torque by the selection of an optimum inverter voltage vector. The selection of the voltage vector of the voltage source inverter is made to restrict the flux and torque error within their respective flux and torque hysteresis bands and to obtain the fastest torque response and highest efficiency at every instant [16]. DTC enables both quick torque response in the transient operation and reduction of the harmonic losses and acoustic noise. With DTC there is no modulator and no requirement for a tachometer or position encoder to feed back the speed or position of the motor shaft. In DC drive armature current and magnetizing current are control variables whereas in DTC, motor torque and motor magnetizing flux are control variable. Both drives use actual motor parameters to control torque and speed which shows better dynamic performance. In DTC [17], no tachometer or encoder is needed feedback a speed or position signal. DTC is the first technology to control the "real" motor control variables of torque and flux. It beneficial because torque and flux are motor parameters that are being directly controlled, there is no need for a modulator, as used in PWM drives, to control the frequency and voltage. DTC also provides precise torque control without the need for a feedback device.

Level Inverter: A five-level inverter-fed induction motor drive scheme is proposed in the present work for simultaneously achieving the dual task of elimination of common-mode voltage and DC-link capacitor voltage imbalances. The proposed scheme is based on a dual five-level inverter-fed open-end winding induction motor configuration [18]. This paper investigates the operating limitations of achieving this dual task for the five-level inverter-fed drive with a single DC power supply. A five-level inverter-fed drive topology with two DC power supplies and a strategy for selecting the switching states, is proposed to achieve the dual task simultaneously. The proposed inverter-fed drive offers a simple power bus structure with more redundant switching states for inverter voltage vectors and demands a lower voltage blocking capacity of the power devices, as compared with a single five-level inverter-fed drive. As only the availability of redundant switching states for the inverter voltage vectors is exploited, the dual task is achieved without disturbing the fundamental component of the inverter output voltage and the scheme does not require any extra control circuit hardware.

Effects of Different Switching-state Combinations on Variation of Capacitor Voltages: For ease of analysis all the inverter voltage vectors of are divided into five main groups as shown in The effects of redundant switching-state combinations of voltage space vectors belonging to each of these groups on the charging and discharging of the DC-link capacitors are studied. Based on the connection of machine phase winding terminals with the DC-link nodes, the currents drawn from the DC-link nodes to the machine phase windings and vice versa are assigned with proper signs, It is found for all the switching-state combinations of voltage vector O0 that there is no flow of currents to or from any of the DC-link nodes as the motor phases are not connected across any of the capacitors. Hence, switching-state combinations of the ZV group do not have any effect on capacitor voltages. A few examples of this are given. For the capacitor voltage balancing point of view, all the switching-state combinations of the ZV group are equivalently represented as 'z, z, z', in terms of the currents flowing through DC-link nodes '1', '0' and '_1' respectively [19].

Simulation Result: Inverters using an induction motor configuration can realize multilevel inverter structures. The voltage across the phase winding of the induction motor can attain one of the five levels –2*V*dc,-Vdc 0,2Vdc or *V*DC, depending upon the switching states of the inverters. The switching combinations of inverter for realizing the different levels in the Aphase of a three-level inverter with IM configuration are shown in Table 2, where Sa1,Sa2,Sa3,Sa4 represent the top switches of Inverter and Sa5, Sa6, sa7, sa8 represents the bottom switches, respectively, for the A-phase.

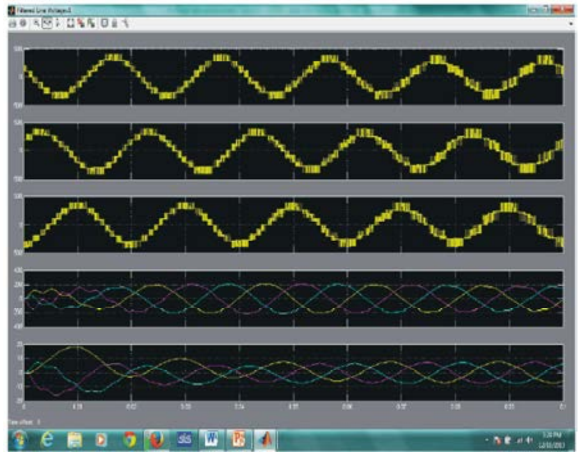


Fig. 2: Voltage & current Balanced condition

Total Harmonics Distortion: This chapter shows how harmonic elimination is done in Inverter by Pulse Width Modulation technique by solving the non linear equations. Equations are used to determine switching angles of an Inverter. In order to form the equation set, fundamental component is given desired output value and all other harmonics are equated to zero. In my simulation I find the switching angles for the 3-level, 5-level harmonics. The equation which is derived for Total Harmonic Distortion of the output voltage of an inverter is used in order to reduce the harmonics that are produced in the inverter. The percentage of the Total Harmonic Distortion is given by the following formula. For different application requirements, we have different optimal goals. For example, here, we assume three cases:

Case 1: Minimum THD and eliminate the 5th, 7th, 11th and 13th harmonics.

The goal is to find a combination with 2*s* + 1 DC voltage levels with minimum THD:

$$THD = \frac{\sqrt{V_{17}^2 + V_{19}^2 + \cdots + V_{49}^2}}{V_1}$$

Case 2: Minimum THD and eliminate the 5th, 7th, 11th, 13th, 17th, 19th, 23rd and 25th harmonics.

The goal is to find a combination with 2*s* + 1 DC voltage levels with minimum THD:

$$THD = \frac{\sqrt{V_{29}^2 + V_{31}^2 + \cdots + V_{49}^2}}{V_1}$$

Case 3: Minimum THD and eliminate the 5-37th harmonics.

The goal is to find a combination with 2*s* + 1 DC voltage levels with minimum THD:

$$THD = \frac{\sqrt{V_{41}{}^2 + V_{43}{}^2 + \cdots + V_{49}{}^2}}{V_1}$$

The switching angles which are required for the THD are calculated as shown in the figures and the simulation codes. The code for THD is also shown in detail. The proposed topology is realized by two types of multilevel inverters, fed from asymmetrical isolated dc voltage sources. Improves the efficiency of the overall system. The work is to be presented in open loop by using PWM.

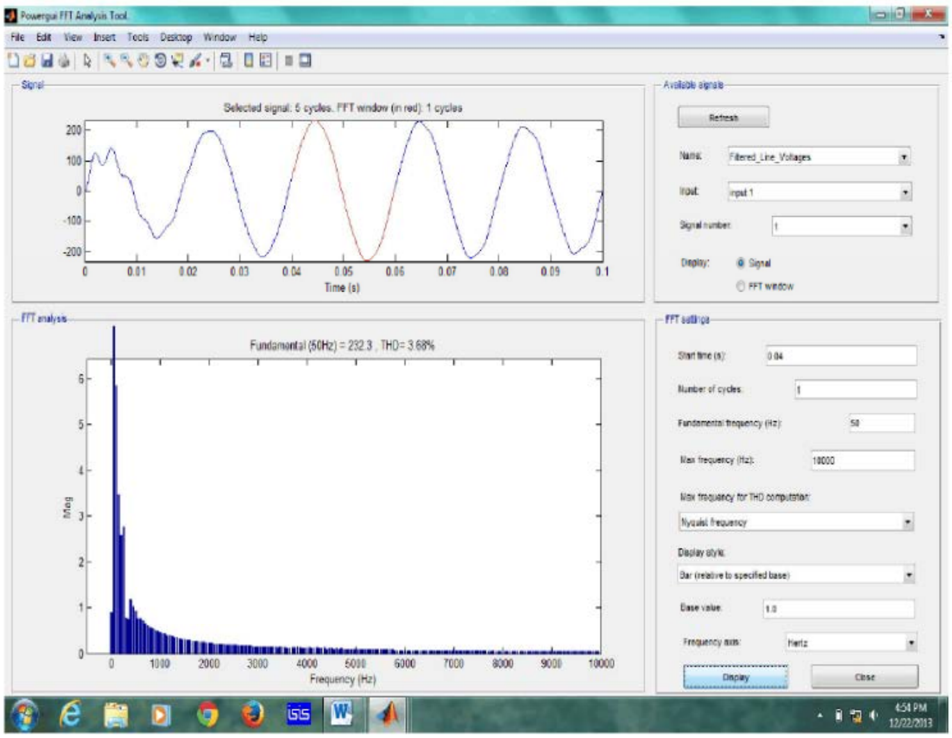


Fig. 3: 5 level voltage THD

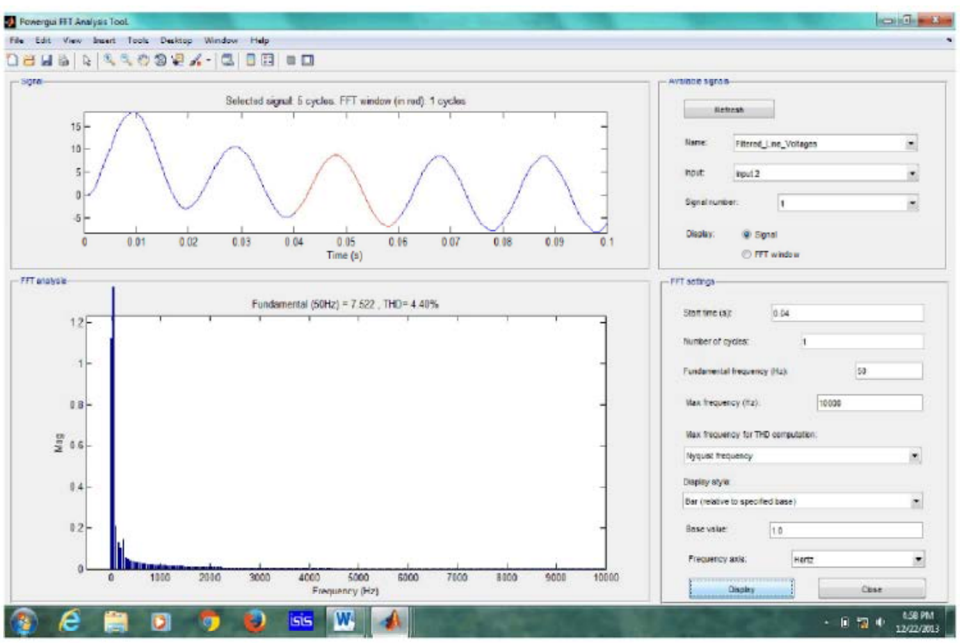


Fig. 4: 5 level current THD

Table 1: voltage & current thd

5-level balanced condition (rpm)	Voltage THD	Current THD
1400,1400	3.68%	4.40%
1350,1300	4.31%	6.32%
1200,1100	3.20%	7.07%
1000,900	4.71%	1.90%
800,700	4.28%	0.99%

In both induction and synchronous motors, the AC power supplied to the motor's stator creates a magnetic field that rotates in time with the AC oscillations Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through external impedance The rotating magnetic flux induces currents in the windings of the rotor in a manner similar to currents induced in a transformer's secondary winding(s). The currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The rotor accelerates until the magnitude of induced rotor current and torque balances the applied load. Since rotation at synchronous speed would result in no induced rotor current, an induction motor always operates slower than synchronous speed. The difference, or "slip," between actual and synchronous speed varies from about 0.5 to 5% for standard Design B torque curve induction motors. The induction machine's essential character is that it is created solely by induction instead of being separately excited as in synchronous or DC machines or being self-magnetized as in permanent magnet motors.

For rotor currents to be induced, the speed of the physical rotor must be lower than that of the stator's rotating magnetic field (n_s); otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. For this reason, induction motors are sometimes referred to as asynchronous motors an induction motor can be used as an induction generator or it can be unrolled to form a linear induction motor which can directly generate linear motion.

CONCLUSION

A weighted vector control of speed-irrelevant dual induction motors fed by the single inverter is proposed. The performance of unbalanced load control is improved by regulating the weight of the vector control. From the simulation and experimental results in multiple induction motors platform, the following Conclusion can be obtained: 1) The weighted excitation current and torque current derived by the weighted vector mode can realize the torque control of speed-irrelevant dual induction motors and distribute the weight of vector control to dual induction motors. 2) In heavy unbalanced load, the propose method completely distributes the weight of vector control to the induction motor at standstill to start at heavy unbalanced load effectively. 3) In sudden change of unbalanced load

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