Variable Frequency Drives to Increase Phase Angle and Voltage Magnitude for Efficient Inverters based upon Dead Time Compensation Method in Smart Grid Technology

Muhammad Fahad Shinwari[1], Sheeraz Iqbal [2], Atta ul Munim Zaki[3], Anton V. Prokhorov[4], Naeem Janjua[5] and Zia ul Islam [6]

1, 2 and 6- International Islamic University, Islamabad, Pakistan
Corresponding Authors*
2 and 3 - Department of Electrical Engineering, University of Azad Jammu and Kashmir Muzaffarabad, Pakistan
4- Tomsk Polytechnic University, Russia
5- Islam College of Engineering and Management Sciences, Sialkot, Pakistan

Abstract— This research paper develops a methodology to improve fundamental voltage magnitude and phase angle output based on dead time compensation method for inverters. The Industrial load is comprised of running Induction motors, generators etcetera. 90% of the industrial load is relied on induction motors. The running induction motor gives way to power losses. Furthermore, parametric values of induction motors are modeled, improved and controlled by Variable Frequency Drives.
Moreover, Fundamental Voltage Magnitude is reduced without compensation and is increased after compensation. Also phase Angle output is distorted without compensation and improved after compensation. The designed system model is simulated for useful graphs. The results are analyzed and compared with primitive work.

Keyword—Variable Frequency Drives, Fundamental Voltage Magnitude, Phase Angle and Dead Time Compensation

1. INTRODUCTION

The paper emphasis upon the inverters efficiency using Dead time Compensation Method. The types and characteristics of Inverter is understood in [1, 2 and 3]. The parameters like sinusoidal load current, reduction of harmonic distortion, torque pulsation and improvement of phase angle are taken in account to increase the efficiency of inverter in smart grid technology. Further the desired graphs of Relation of Inverter, Variable Frequency Drive and Induction Motor with Smart Grid [4 and 5].

Here we discuss smart grid and its parameters briefly. In first section we discussed literature review. Then we discussed different terminologies for example grid, smart grid, smart grid parameters, smart grid history and importance of smart grid. After brief discussion related to smart grid we discussed the inverter and also characteristics of inverter.

Variable frequency drive and induction motor also discussed briefly.

The future electric smart grid would act as a hub for consumers, Renewable Energy, Communication, Storage, Micro grid and conventional Power Plants.

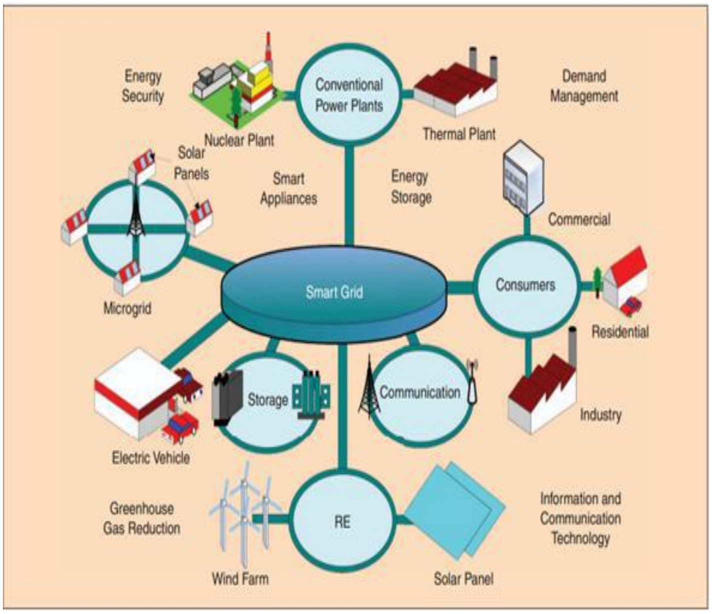

Figure. 1.1 Future electric grid

Inverter plays a very important role in Power conversion system. It is also used in industrial electronics and we also need it in renewable energy system. For example it is used in solar panels and wind turbine. The reason is that most of the micro generation happens in DC, but then if we want to use that power, we have to make it useable to steady appliances, that run on AC.

Basically inverter is used for conversion of DC (direct current) to AC (alternating current).

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DC, but then if we want to use that power, we have to make it useable to steady appliances, that run on AC.
In some cases in which power generation is already in AC, it has to be converted into DC and then back into AC. The reason is that the produced energy can be stored into batteries. The batteries require DC charging current. In wind generator the AC current
does not have the correct frequency and correct amplitude which is required for appliances.

Types of inverter

1) Standalone
2) Grid tie inverters
In the stand alone inverter

In the stand alone inverter, their work is just to convert DC into even AC, with specified voltage amplitude and correct frequency. We can connect any appliances to these inverters. In some events the quality of the AC output of the inverter is not suitable for some appliances. Because it depends on the wave shape of the AC output, that can be square, or a quasi-square. The output is also in sine wave (best).
In the second case, instead of the inverter output is connected to the power grid. The power is injected into the main distribution network.

2. PROPOSED ARCHITECTURE

2.1 Proposed Flow Chart

The Block diagram gives a sketch of our research proceedings. The whole thesis is divided into different phases. The first phase defines the necessary terminologies regarding smart grid and understanding of different terms of smart grid and its parameters.

My focus on the smart consumption which is the domain of Smart Grid. The second phase deals with industrial load. In this phase we see that Industrial load is most important load. One third of total energy consumption due to industrial load by the use of induction motor 90% of industrial loads depends on induction motor. Figure 2.1 shows proposed flow diagram of the research carried out.

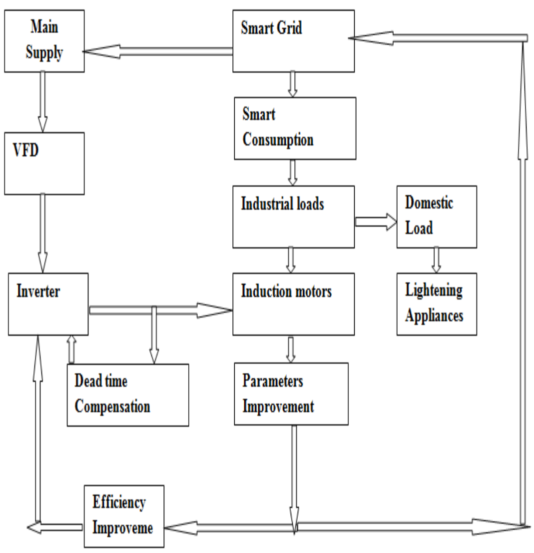

Figure. 2.1

We try to save energy and mostly focus on improvement in the efficiency of overall system. In this phase we are trying to increase the efficiency of inverter. We have used variable frequency drive, it helps us to convert the electric power [6, 7, 8, 9, 10 and 11].
In second part, which is the important phase on which we have worked on improving the inverter efficiency by using a new approach called Dead Time Compensation. It is the important stage of our research in which we will improve the different parameters of induction motor for example fundamental voltage, Phase angle, reduce the harmonic distortion and also reduce torque pulsation.
After achieving the desired modeled system for our exquisite work, then we have implemented our findings through simulation software i-e Matlab. We plot the parametric equations with parametric values according to their certain characteristics. Then the software carries out the simulation for the desired modeled system, which gives rise to the utile graphs. These graphs are further compared and analyzed for essential findings [12, 13, 14, 15 and 16]
.
The parametric equations are given certain parametric values. By several methods, we improve the parameters of induction motor though Dead time compensation ultimately increasing the efficiency of inverter.
The findings are concluded succinctly with future work recommended.

3. RESEARCH METHODOLOGY

The research methodology adopted to optimize the inverters efficiency is to carry out literature review meticulously. Further understand the important parameters of inverter and their types. And what factors and methods could be adopted to improve the efficiency of induction motors.

3.1 Importance of Inverter in improving efficiency of induction motors and its ultimate effect on smart grid

In 1960 the first inverters were made. They had some sort of specific application due to the compact and reliability of the solid state devices of those days. In the 1980‘s when higher power transistors were widely available the bulky inverters were formed and many more applications came up. These devices used linear amplifiers and it controls their overall basic operation. Dip switches and small potentiometers were used to set their operating characteristics. The digital control started in 1990‟s to be used mostly in inverters. Solid state inverters were also formulated that permitted higher voltage and higher current ratings. Due to this it is possible for the inverters to be utilized on larger motors. Microprocessors have played important role and also made the Inverter a much more skilled device. In the last ten years they have turn it more reliable and flexible. Variable frequency drive controlled the induction motors.

3.2 What is Variable Frequency Drive (VFD)?

The construction of machines contains three major parts; prime mover also known as motor or engine, the machine system, and the transmission system. The transmission system consists of gears, shafts or pulley. To control and keep the machine working in motion, the arrangement required is known as drive that is combination of prime mover and the transmission system.
The electric drive is an organize equipment, developed to convert electric energy input into mechanical energy output. Thus electric drive may be defined as a form of equipment, designed to help motor in conversion process of electric energy into mechanical energy or

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―drive‖ is an arrangement which keeps the working machine in motion. It also provides control to the machine.

4. Literature review

In recent years, the new techniques formulated for voltage fed pulse width modulation (PWM) inverters have acquired thick attention in induction motor drives. Recently introduced switching devices in the pulse width modulation (PWM) inverter such as MOSFET, IGBT and others have very quick switching frequency almost above tens of kilohertz. It is intelligent to put in a switching time delay to prevent the conduction overlapping of the switching devices like MOSFET and IGBT. In resultant in Dead Time Effect which creates severe output voltage distortions, heat the winding of induction motor and also create torque pulsations. Extraordinary efforts have been made to compensate the Dead Time errors [12]–[17].
In the research material, the relation between distortion and carrier wave frequency was highlighted in [12]. The Dead Time Effect was measured by calculating the deviation of voltage over a half cycle of the inverter [13]. Two compensation techniques of improvement of the reference wave and logical combination of pulse width modulation (PWM) signals were suggested. The pulse width modulation (PWM) scheme in [14] introduced a distorted voltage compensation technique to eliminate zero current clamping. And more recently, a pulse-based method has been introduced by Leggate and Kerkman for the Dead Time Compensation without considerable magnitude and phase errors in the output voltage of the inverter [15]. The technique is independent of carrier frequencies, operating frequency and also load, but it demands double sampling per carrier period. Muñoz and Lipo formulated a Dead Time Compensation method based on a fast back calculation of current phase angle [16]. A technique for both zero current crossing and dead time effect compensation was also proposed by Ben Brahim [18, 19, 20 and 21].
This research develops a state of the art technique for improving the inverters efficiency based upon the dead time compensation method. Moreover, several other parameters are also improved. Such as, sinusoidal load current, improvement of phase angle, reduction of harmonic distortion and torque pulsation, increase of fundamental voltage magnitude are taken in account [22, 23, 24, 25 and 26].

Significance of VFD

No Benefits Of Variable Frequency Drive (VFD)
1 Energy savings
2 Low motor starting current
3 Reduction of thermal and mechanical stresses on motors and belts during starts
4 Simple installation
5 High power factor
6 Lower KVA

Most Important Industrial Load

Induction motor is most important industrial load. Some examples of the usage of induction motor are fans, the driving pumps, the elevators, the compressors and machinery of several types. Most of the induction motors are variable frequency drive (VFD) controlled. It is one of the simplest power conversion devices of all time. Induction motor has only one moving component. Mostly, if the motor has some ball bearings, and the ball bearings are moving components, then it must have more than one moving part of an induction motor. In any other situation, they are very simple, and also reliable. When voltage is applied on the stator, a voltage is induced in the stator coil of induction motor. The current is flow in the stator and also rotor due to induced voltage. The induction motor design is such that the magnetic fields of the two currents act oppose each other. Due to this behavior it causes a force on the rotor and it compels the rotor to rotate. The Engineers who designed these three phase motors have done a wonderful work in making motors with a very high efficiency and also maximum power factor. Its efficiencies are above 90% and power factors are also almost 80%. Efficiencies and are common at maximum load. Some superior motors have the 90% power factors when maximum loaded.

1. **Industrial Load Requirements**

- Constant torque
- Constant horsepower
- Variable torque

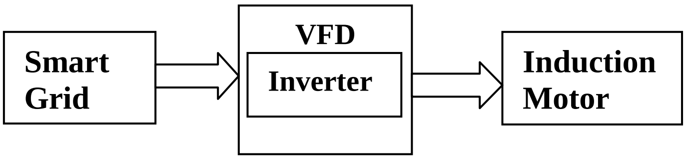
No	Types of Load	Applications
1	Constant torque	Machines (Conveyors, The General machinery, Printing presses, Positive displacement pumps, Hoists.)
2	Constant horsepower	In The Machinery (The wheel grinders, driven reels, Winders, core and Heavy driller machines.)
3	Variable torque	Fans and Pumps (Fans, centrifugal blowers, centrifugal pumps, propeller pumps.)

4.1 Relation of Inverter, Variable Frequency Drive and Induction Motor with Smart Grid

These are three different electronic and power gadgets and each of them has separate significance. But here all of these are combined and working for us [27, 28 and 29].
In industry VFDs and Inverter are the words which are used interchangeably. Inverter is basically the most important component of VFD. VFDs are used in industry for speed control of induction motors and also help induction motors in start. The drives are very useful for starting the motors where they take five to six times more than the rated current. Drives prove their importance by starting motor at reduced frequency and voltage and also on low speed and keeping current requirement low and within safe limit to avoid voltage dip.
Induction motors are backbone of our industry as 90% load in industry is driven by induction motors. The induction motors are started and controlled by Variable Frequency Drives [30, 31 and 32].
Smart Grid in our case is utility which is supplying us power. We are getting power from Smart Grid to run Induction Motor by the help of Variable Frequency Drive. Inverter and Variable frequency Drives are helping us to efficiently utilize the energy that we are getting

from Smart Grid and also reduce the risks of transients and any kind of instability on Smart Grid.

This is very important relation between these components and has significant effect in utilizing the energy from smart grid as our focus in this research is on distribution side of Smart Grid.



5. RESULTS

The simulated result is given below along with table

5.1 Greater Fundamental Voltage Magnitude

The reduction in magnitude of fundamental voltage and also distortion due to dead time which is compensated with the help of systematic approach of dead time compensation. The Dead Time Compensation reduces the harmonics as well as increases the magnitude of the voltage. This effect is shown in the figure 5.1.

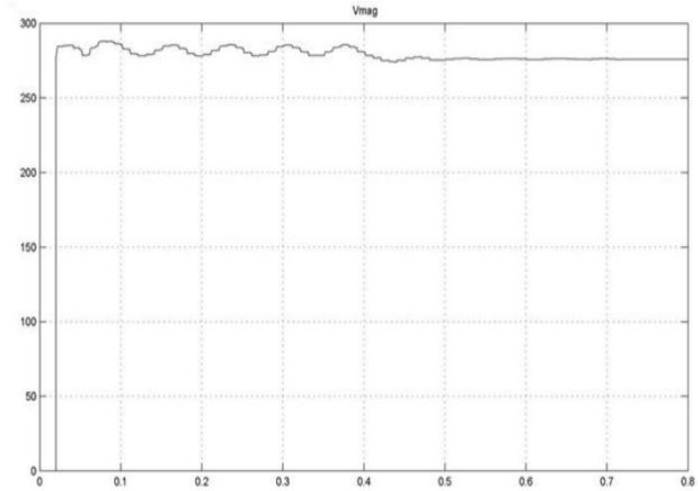
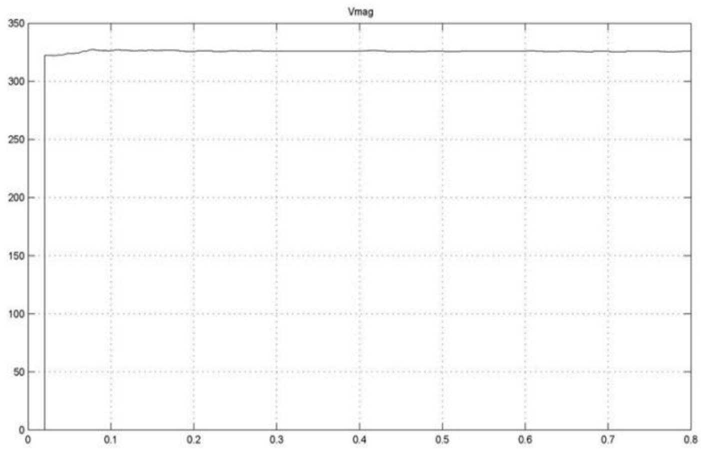


Figure. 5.1 Fundamental Voltage (Va) magnitude reduction and distortion without compensation (dead time = 10 µs)



Fundamental voltage (Va) magnitude improvement after compensation (dead time = 10 µs)

Figure 5.2 Compensation Effect on Fundamental Voltage

5.2 Improved Phase Angle of Fundamental Voltage

The voltage phase angle is also distorts by the Dead time but we are using the Dead time compensation technique. By using this technique the angle become quite close to the desired value. Figure 5.3 shows the results.

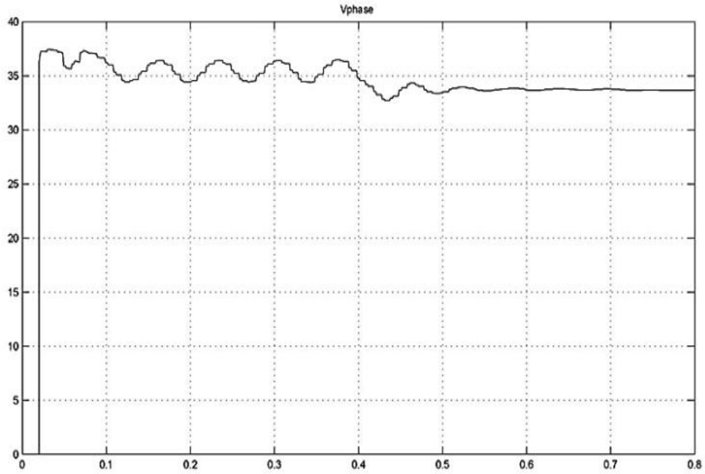


Figure. 5. 3 Phase distortion of fundamental voltage (Va), without compensation (dead time = 10 µs)

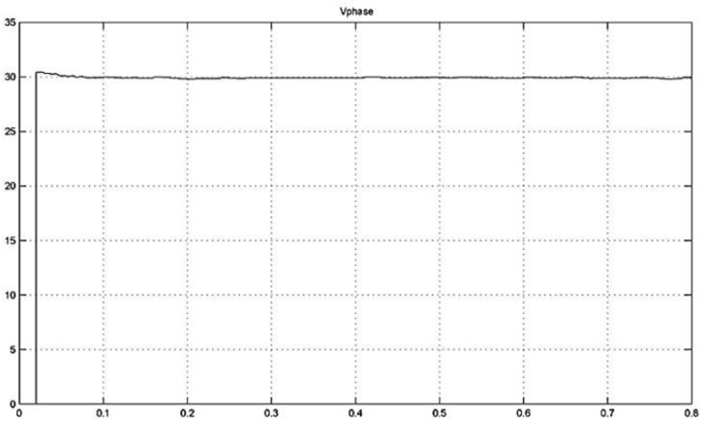


Figure. 5.3 Improved phase angle of fundamental voltage (V_a) after compensation (dead time = 10 µs)

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OUTCOMES OF RESEARCH

NO.	Parameters	Without Compensation	After Compensation
1	Torque	Torque Pulsation	Reduce Torque Pulsation
2	Fundamental Voltage Magnitude	Reduction of Fundamental Voltage	Increase Fundamental Voltage Magnitude
3	Phase Angle of Output	Distortion	Improve Phase Angle

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