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# Grid Current Shaping And Under Voltage Effect Of Induction Motor Using MPC Technique

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**Abstract**

This paper deals with the grid current shaping methods and under voltage effect of three phase induction motor drive system using dc link shunt compensator(DSC). The proposed method satisfies the grid regulation IEC 61000-3-12 without any power factor correction circuits or the input filters. The proposed Luo-converter acts as dc link shunt compensator. The control of proposed Luo- converter is employed by PI controller. The under voltage of induction motor is regulated by boost converter and the control technique employed is Model predictive control. In this paper the grid current harmonics are reduced and the voltage is maintained constant. The detailed simulation study of grid current harmonics has been carried out in MATLAB software.

***Key Words*:**Grid current shaping, Luo- converter, Model predictive control, Under voltage effect.

# 1 INTRODUCTION

Advancement in power electronics technology have enabled the variable speed or motor drives to be used for various adjustable speed applications such as ventilation and air conditioning systems, applications involving pumps and fans , combustion air for boiler systems, chillers and water pumping systems. The variable speed drives consists of single phase diode rectifier three phase inverter and dc link capacitor. In order to maintain the voltage constant the dc link capacitance must be designed as high value. The passive components like grid filter inductor and dc link capacitor is used to smooth the output power and reducing the grid current harmonics. The electrolytic capacitor is widely used as the dc link capacitor due to its high capacitance per volume. However it has some drawbacks. First, the electrolyte in that capacitor evaporates and it has large current ripple and produces more heat. So, the life time of the dc link reduces drastically. Due to the short life time the driver circuit is prone to failure.

In the proposed method, the grid current shaping is achieved with a dc link shunt compensator[2]. The Luo- converter acts as DSC and can satisfy the grid regulation IEC 61000-3-12 without using heavy grid filter inductor. Luo- converters are series of DC-DC converters which provides high transfer gain with reduced number of components compared to other converters. PI control is employed in Luo- converter. Also under voltage effect on induction motor is considered and the voltage is regulated whenever there is a voltage drop occurs. This is realized by using boost converter and the low voltage is balanced. A new model predictive control is employed here. The voltage is maintained constant throughout the operation.

Therefore, torque ripple free output and more efficient motor drive system is obtained using DSC. The harmonics are greatly reduced in this proposed method. The output of the proposed system is verified by simulation results.

## 2 BLOCK DIAGRAM

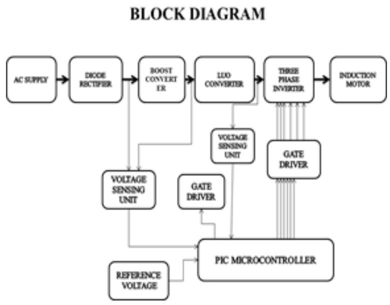


Figure 1- Proposed system block diagram

The figure 1 shows the block diagram of the proposed system. Three phase AC supply is given to a diode rectifier circuit which converts AC voltage to DC voltage. This voltage is fed as an input to the boost converter which regulates the given input voltage to the required voltage. The output voltage from the boost converter is given as an input to the dc link shunt compensator. Here Luo-converter act as DSC. The constant voltage is maintained and grid current shaping is done in this system. The dc output voltage is fed to the three phase inverter where it is converted into AC output voltage. This output voltage is fed as an input to the motor drive system and the speed is maintained constant throughout the operation. Here voltage sensing unit is used at various stages to sense the voltage and current. The gate driver circuits are used to generate the gate pulses to the converter and inverter circuit. PI control is employed to control the operation of Luo- converter, Model predictive control is employed for boost converter and sinusoidal pulse width modulation technique is employed for the control of three phase inverter. All these control techniques are carried out in PIC micro controller.

# 3 GRID CURRENT SHAPING METHOD

Grid current harmonics are generally caused due to non linear loads such as Static VAR compensators, inverters, DC-DC converters, SMPS and AC or DC motor drives. In the case of a motor drive, the AC current at the input to the rectifier looks more like a square wave than a sine wave (see Figure 2). Typical 6-Pulse Rectifier Input Current Waveform

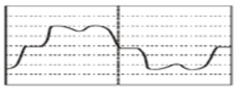

Figure 2- Input current waveform of rectifier

The rectifier can be thought of as a harmonic current source and produces roughly the same amount of harmonic current over a wide range of power system impedances. Proper DC link design can minimize the presence of inter harmonics. In the proposed method, Luo-converter acts as DC link shunt compensator. By maintaining the dc link voltage constant the current harmonics are reduced and grid current shaping can be done.

## 3.1 LUO- CONVERTER

In this paper Luo- converter[1] acts as dc link shunt compensator. It helps in maintaining the dc link voltage constant thereby giving ripple free output voltage and current. The figure shows the elementary circuit of the positive output Luo- converter and its operation during switch on and off operation. The voltage lifting technique helps in reducing the effect of parasitic elements and it opens a way of improving the circuit characteristics. The converter employs voltage lift technique that differs from other available DC to DC step-up converter and are featured with simple structure and operation.

### 3.1.1 ELEMENTARY CIRCUIT OF LUO- CONVERTER

Here the Capacitor C acts as the primary means of storing and transferring energy from the input source to the output load via the pump inductor L1. Assuming capacitor C to be sufciently large, the variation of the voltage across capacitor C from its average value Vc can be neglected in steady state, i.e., Vc(t)  Vc, even though it stores and transfers energy from the input to the output.

### 3.1.2 CIRCUIT DIAGRAM

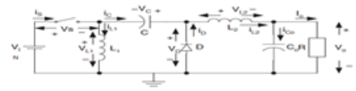

Figure 3- circuit diagram of Luo- converter

### 3.1.3 SWITCH-ON MODE

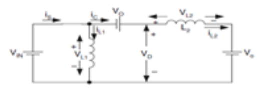

Figure 4- On state diagram

### 3.1.4 SWITCH-OFF MODE

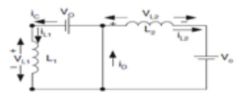

Figure 5- Off state diagram

### 3.1.5 DISCONTINUOUS MODE

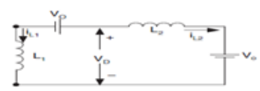

Figure 6- Discontinuous mode circuit diagram

The figure shows the Elementary circuit of positive output Luo–converter (3) Circuit diagram (4) Switch-on mode (5) Switch-off mode (6) Discontinuous mode. When switch S is on, the source current $i_1 = i_{L1} + i_{L2}$. Inductor L1 absorbs energy from the source. In the mean time inductor L2 absorbs energy from source and capacitor C, both currents iL1 and iL2 increase. When switch S is off, source current $i_1$= 0. Current iL1 ows through the free-wheeling diode D to charge capacitor C. Inductor L1 transfers its stored energy to capacitor C. In the mean time current iL2 ows through the

(Co R) circuit and free-wheeling diode D to keep itself continuous. Both currents iL1 and iL2 decrease. Actually, the variations of currents iL1 and iL2 are small so that$i_{L1} \sim I_{L1} and i_{L2} \sim I_{L2}$. The charge on capacitor C increases during switch off:

$$Q_{+} = (1-k)TI_{L1} \tag{1}$$

It decreases during switch-on:

$$Q_{-} = kTI_{L2} \tag{2}$$

In a whole period investigation, $Q_{+} = Q$. Thus,

$$I_{L2} = \frac{(1-k)}{k} I_{L2} \tag{3}$$

Since capacitor Co performs as a low-pass lter, the output current

$$I_{L2} = I_0 \tag{4}$$

These two Equations are available for all positive output Luo-Converters. The source current is$i_I = i_{L1} + i_{L2}$ during switch-on period, and$i_I = 0$ during switch-off. Thus, the average source current II is

$$\frac{V_0}{V_1} = \frac{k}{1-k} \tag{5}$$

## 3.2 PI CONTROL FOR LUO-CONVERTER

Many process in industries are non-linear and it is difficult to be mathematically described. As we know, most of the non-linear process can be controlled using PID controllers if the controller parameters are known. Practical study proves that this sort of control has a lot of sense because it is quite simple and based on three basic modes: proportional (P), integral (I) and derivative (D). Inspite of using complex controllers, a large number of PID controllers are used to control complex processes in industrial applications. The different types of controllers such as P, PI and PD are basic blocks various control processes. Even though they are simple, if it is combined with different functional blocks such as compensators, correction blocks, filters, comparators or selectors etc., they can be used to solve very complex problems. For many complex control systems, the PID controllers are expected to be the backbone. The proportional and integral modes are often used as single control systems, and derivative mode is rarely used. PI controller forms the control signal in the following way:

$$U(t) = K_p[e(t) + \frac{1}{T}\int_0^t e(\tau)d\tau] \quad (6)$$

#### 3.2.1 PROPORTIONAL FUNCTION

The output of controller u is proportional to error signal e:

$$u = k_c e = \frac{1}{\delta}e \quad (7)$$

$\delta$=propotional band

#### 3.2.2 INTEGRAL FUNCTION

The output of controller is proportional to error e.

$$\frac{du}{dt} = S_o e \rightarrow u = S_0 \int_0^t edt \quad (8)$$

- constant output and e=0 hence no steady state error.
- System stability is reduced. I control is comparatively slower than P control.
- S0 is proportional to open loop gain, when S0 increases system stability decreases.

#### 3.2.3 PI CONTROL

P control is to reject disturbance and to improve response time,

I is for eliminating steady state error,

$$u = K_c e + S_0 \int_0^t edt = \frac{1}{\delta}(e + \frac{1}{T_1}\int_0^t edt) \quad (9)$$

#### 3.2.4 CONTROL BLOCK DIAGRAM OF DSC WITH PI CONTROLLER

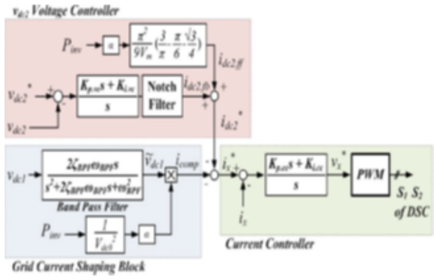


Figure 7- Control block of DSC

# 4 UNDER VOLTAGE EFFECT AND BALANCING METHOD

In AC induction motors the peak torque that is used to accelerate it from a stop condition is proportional to the square of the change in voltage[12]. When the voltage is 80% of normal, the peak torque of the induction motor will only be 64% of normal value; if the voltage is 70% of normal, the torque will be less than half of the available peak torque. It means the induction motor can easily able to stall and if it does not happen so, the slip of the motor will increase and it start pulls the same current, but will do less work. Hence the efficiency becomes poor and energy consumption will be more and the motor will become heat. Or if it does the same work, it will draw more current and hence the current harmonics increases. In this paper, boost converter is used to overcome these drawbacks and to enhance the voltage during under voltage condition.

Figure 8- Circuit diagram of boost converter

## 4.1 BOOST CONVERTER CONFIGURATION

Boost converter is a series of DC-DC converter and also called step-up converter. In this converter, the output voltage is always higher than the input voltage and so the name boost. The circuit diagram of boost converter using MOSFET is shown in the figure.

The operation of boost converter is generally divided into following two modes. They are Mode 1 and Mode 2. Mode 1 starts at transistor M1 is switched on at time t=0. The input current starts flowing through the inductor L and transistor M1. Mode 2 starts at transistor M1 is switched off at time t=t1. The input current now starts flowing through inductor L, Capacitor C, load, and diode Dm. The inductor current gradually falls until the next cycle. The energy stored in inductor L flows through the load.

The circuit diagram of two modes of operation are shown below:

Figure 9- On state circuit diagram

Figure 10- Off state circuit diagram

The voltage and current relation of the inductor L is:

$$i = \frac{1}{L}\int_0^t V dt + i_0 \tag{10}$$

OR

$$V = L\frac{di}{dt} \tag{11}$$

For a constant rectangular pulse:

$$i = \frac{V_t}{L} + i_0 \tag{12}$$

When M1 is switched on:

$$i_{pk} = \frac{(V_{in} - V_{Trans})T_{on}}{L} + i_0$$

or

$$\Delta i = \frac{(V_{in} - V_{Trans})T_{on}}{L} \quad (13)$$

when M1 is switched off the current is:

$$i_0 = i_{pk} - \frac{(V_{out} - V_{in} + V_D)T_{off}}{L}$$

or

$$\Delta i = \frac{(V_{out} - V_{in} + V_D)T_{off}}{L} \quad (14)$$

Here the voltage drop across the diode Dm is VD, and VTrans is the voltage drop across the transistor M1. By equating, we can solve for Vout:

$$\frac{(V_{in} - V_{Trans})T_{on}}{L} = \frac{(V_{out} - V_{in} + V_D)T_{off}}{L}$$

$$V_{in} - V_{Trans}D = (V_{out} + V_D)(1 - D) \quad (15)$$

$$V_{out} = \frac{(V_{in} - V_{Trans})D}{(1 - D)} - V_D \quad (16)$$

The voltage drop across the transistor and the diode is neglected:

$$V_{out} = \frac{V_{in}}{1 - D} \quad (17)$$

So it can be seen that the output voltage is directly proportional to the duty cycle and the inductance is inversely related to the ripple current. So a large inductance should be used to reduce the ripple.

## 4.2 MODEL PREDICTIVE CONTROL (MPC) TECHNIQUE

Boost converter exhibits poor voltage regulation when it is operated in open loop mode. Hence this converter is always operated in closed loop with controller for output voltage regulation. The unregulated DC voltage is given as the input to the system, and regulated DC voltage is the output. The problems associated with using converter are:

1. It may be non linear system.
2. Dicrete values for switching positions. Discontinuous switching is not efficient for the control of output voltage.
3. Maintainence of input and output state constraints ares difficult.

In this paper, the control technique employed is Model predictive control. The work of MPC[7] is optimization over the manipulated inputs and forecasting the behavior of process. The forecast is done using process model, and the model is the important element of MPC controller. The advantage of MPC is that multivariable problems can be handled easily.

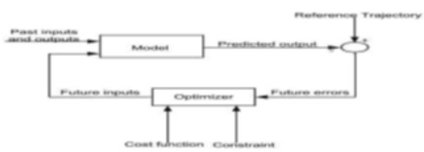


Figure 11- Block diagram of MPC

There are many methods available for the control of time-invariant linear systems but there exists only few methods for time varying linear systems and still fewer for non linear systems. The working of a Model Predictive Control system can be explained with the illustrated diagram.

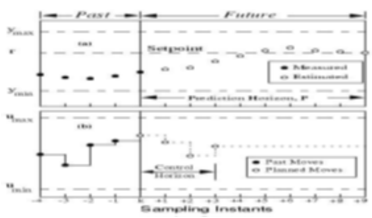


Figure 12- Working of Model Predictive Controller

The fig 12(a) shows the MPC system that is operating for many sampling instants. The current instant is represented by k. y, k are measured latest outputs and y k-1, y k-2... are previous measurements and are known. They are filled circle in Fig 12(a). The u k-41... u k-1 are previous measurements in fig 12(b) and they are filled circles. Asusual, each move from the controller is received by a zero hold order. Until the next sampling instant it is held constant, owing to step-wise variations. To calculate the next move u k the controller operates in two modes estimation and optimization.

## 4.3 MPC TOOLBOX IN MATLAB SIMULINK

The Model Predictive Control Toolbox is a collection of software that helps in designing, analyzing, and implementing industrial automation algorithm. As other available MATLABtools, it is also providing a graphical user interface (GUI) and also command syntax.

A MPC toolbox employs control mechanism by the combination of prediction and control strategies. The prediction is provided by an approximate system model. The prediction system signals is compared against set of objectives by the control strategy, and the available actuators are adjusted for achieving the objectives by respecting the system constraints. Like the Control System Toolbox and System Identification Toolbox the MPC Toolbox also uses the same linear dynamic modeling. Transfer functions, state-space matrices, or a combination are all employed. Model Predictive Control can be designed and simulated in the system using simulink, commands or mpctool.

## 5 MATLAB SIMULATION RESULTS

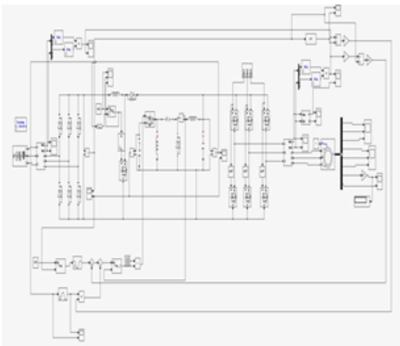

Figure 13- MATLAB CIRCUIT

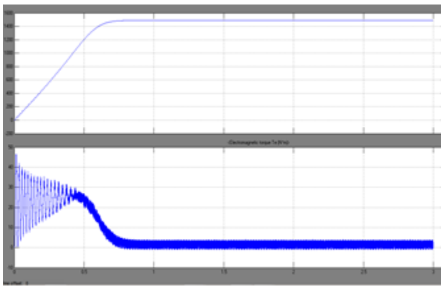

Figure 14- SPEED AND TORQUE WAVEFORM

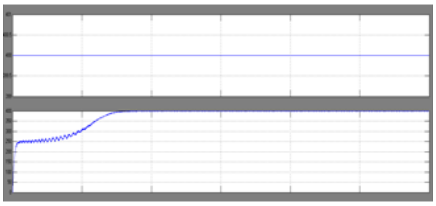

Figure 15- DC LINK VOLTAGE WAVEFORM

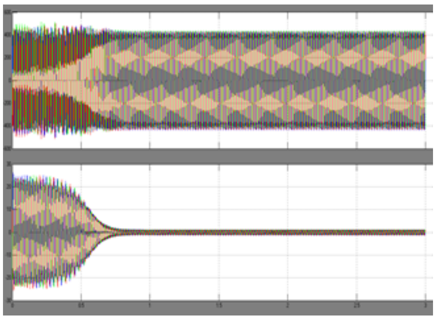

Figure 16- INPUT VOLTAGE AND CURRENT WAVEFORM

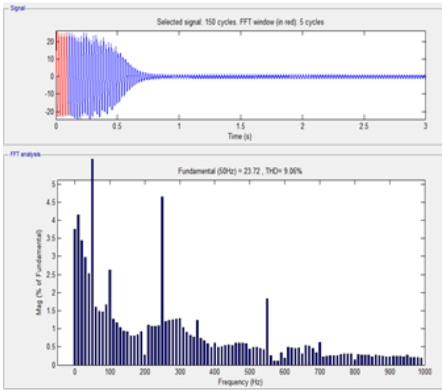


Figure 17- PROPOSED SYSTEM- THD

## 6 ACKNOWLEDGEMENT

We would like to show our gratitude to our guide Mrs. R. Suguna who helped us a lot to do this project titled Grid current shaping and under voltage control of Induction motor uses Model Predictive Control Technique. This project also helped us to learn many new things.

## 7 CONCLUSION

Grid current shaping and under voltage effect of Induction motor using Model Predictive Control Technique is the proposed system. In this paper the grid current is shaped and the harmonics are reduced. For this purpose Luo-Converter is used with PI controller and the result of the matlab simulation is THD=9.06%. Also under voltage is balanced using boost converter. A new Model Predictive Control technique is employed for the control of converter. The voltage is maintained constant throughout the operation. Hence the speed is also maintained constant and the efficiency of the total motor drive system is improved.

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