

# **Adaptive Speed Control of Three phase Induction Machine using Variable Frequency Drive in Thermal Power Plant**

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**ABSTRACT:** There are several terms used to describe devices that control speed. This project proposes how the Variable frequency drive uses power electronics to vary the frequency of input power to motor, thereby controlling motor speed. AC motor drives are widely used to control the speed of pumps, blower speeds, machine tool speeds, conveyor systems speeds and others applications that require variable speed with variable torque. In this project the variable frequency drive is proposed instead of throttling of output of the Condensate Extraction Pump (CEP) which is connected to a induction motor running at constant speed. Using Variable Frequency Drive (VFD) the speed of the induction motor gets varied according to the load requirements. The complete proposed system consists of an ac voltage input that is put through a Vienna rectifier to produce a dc output which across a shunt capacitor, this will, in turn, feed the Z source inverter. The Z source inverter is controlled to produce a desired sinusoidal voltage at a particular frequency, which is filtered by the use of an inductor in series and capacitor in parallel and then through squirrel cage induction motor. This induction machine is then controlled by the field oriented control. The speed control is achieved by adapting itself to all the constraints. In the vector control scheme, a complex current is synthesised from two quadrature components, one of which is responsible for the flux level in the motor, and another which controls the torque production in the motor. And these parameters are compared with a set value and the error is calculated using adaptive gain scheduling method as per variations in load. The proposed method is implemented through the MATLAB/ SIMULINK software. The models of Vienna rectifier, Z source inverter, induction machine, field oriented method, gain scheduling and the process involved are done.

**KEYWORDS:** Throttling, Condensate Extraction Pump, Variable Frequency Drive, field oriented control.

## **I. INTRODUCTION**

At a high level, control system theory serves as a basic building block of most modern mechanical systems. By applying the appropriate type of control, you can design systems to perform tasks within an amount of time, at specific levels of granularity. Broadly, we can look at control theory as being classified into open loop control or closed loop.

Because of its self-adjusting nature, closed loop control systems are more complex. In these systems, amplifiers can return data back to the input stage, which can then adjust itself based on the information received. An example of this in a physical system is when the output is position - amplifiers that control velocity and position can provide feedback at a consistent rate. One way in which we can accurately control the process is by monitoring its output and “feeding” some of it back to compare the actual output with the desired output so as to reduce the error and if disturbed, bring the output of the system back to the original or desired response. The measure of the output is called the “feedback signal” and the type of control system which uses feedback signals to control itself is called a **Close-loop System**.

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Vector control, also called field-oriented control (FOC), is a variable-frequency drive (VFD) control method where the stator currents of a three-phase AC electric motor are identified as two orthogonal components that can be visualized with a vector[3]. One component defines the magnetic flux of the motor, the other the torque. The control system of the drive calculates from the flux and torque references given by the drive's speed control the corresponding current component references. Typically proportional-integral (PI) controllers are used to keep the measured current components at their reference values. The pulse-width modulation of the variable-frequency drive defines the transistor switching according to the stator voltage references that are the output of the PI current controllers. In vector control, an AC induction or synchronous motor is controlled under all operating conditions like a separately excited DC motor. That is, the AC motor behaves like a DC motor in which the field flux linkage and armature flux linkage created by the respective field and armature (or torque component) currents are orthogonally aligned such that, when torque is controlled, the field flux linkage is not affected, hence enabling dynamic torque response[5]. The control variables of an AC induction motor are made stationary (DC) using mathematical transformations. In a way, FOC tries to control an induction motor by imitating DC motor operation as it deals with stationary parameters. The two possible methods for achieving field orientation are direct flux orientation where the field orientation is achieved by direct measurement or estimation of the flux, and indirect field orientation where the field orientation is achieved by imposing slip frequency derived from the rotor dynamic equations. The field orientation with respect to the rotor flux alone gives a natural decoupling between two components, fast torque response and stability; whereas the stator and air-gap flux decoupling control methods give nonlinear torque-slip characteristic with limited starting torque capability, though these methods are having ease of flux computation.

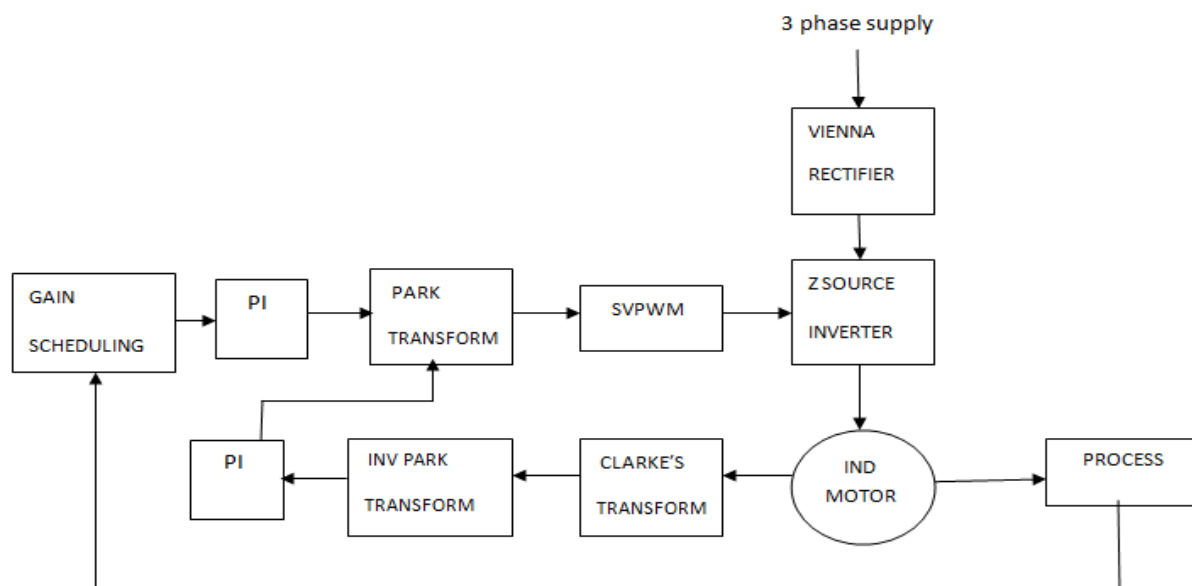


Fig. 1 Block diagram of Field oriented control

Paper is organized as follows. Section II describes the variable frequency drive which consists of Vienna rectifier and Z source inverter. The block diagram represents how the induction motor speed is controlled using field oriented control. After the transformations how the gain scheduling is implemented that is given in Section III. Section IV presents overall simulink diagram and Section V presents experimental results showing results of rectifier, gain and rotor speed. Finally, Section VI presents conclusion.

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## II. VARIABLE FREQUENCY DRIVE

Variable Frequency Drives (or VFDs) are becoming almost standard part of aquatics equipment room packages. Most VFDs are fairly simple to install and operate however, they are quite complex with respect to their sophisticated hardware and software implementations. VFD functionality and operation can be greatly improved by understanding basic VFD theory, terminology and interfacing options. VFD is a power conversion device[1]. The VFD converts a basic fixed-frequency, fixed voltage sine-wave power (line power) to a variable-frequency, variable-voltage output used to control speed of induction motors. A VFD (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage[2]. The VFD controller is a solid-state power electronics conversion system consisting of three distinct sub-systems: a rectifier bridge converter, a direct current (DC) link, and an inverter.

### A. Vienna Rectifier:

In this project the VFD uses the vienna rectifier. It is a three phase, three levels and three switch rectifier; it is kind of PWM (Pulse Width Modulation) rectifier with controlled output voltage[7]. The topology of the Vienna Rectifier is a combination of a boost DC\DC converter with a three-phase diode bridge rectifier. The input current for each phase is defined by the voltage applied across the corresponding inductor; the input voltage of the rectifier is determined by the switching state and the input current direction[8]. The input inductor charge when the switch is on and the current increase in the inductor, and when the switch is off the inductors discharge through the positive or negative diode depending on the current flow direction. The existence of an input inductor creates a current source at the input while the capacitors create output voltages[11].

### B. Z source Inverter:

Also the proposed system uses Z source inverter. An alternative power conversion topology that can buck or boost the input voltage / current with linear and non-linear load depending upon duty ratio and modulation index in a single stage conversion with the help of Impedance source passive Network (L and C), is usually known as Z-Source[13]. The unique feature of Z-Source network is shoot-through duty cycle and it acts as a filter which reduces the line harmonics, improves power factor, increases reliability and extends the output AC voltage range of inverter.

The classic boost converter is not a good choice for the high step-up conversion due to following three reasons. Firstly, an extremely high duty-cycle must be used to obtain the steep conversion ratio, which causes serious losses on the power devices due to their parasitic parameters[14]. Secondly, low on-resistance active switches and good performance diodes cannot be adopted due to the high voltage stress. Third, the reverse-recovery problem of the output diode is severe due to its short conduction time. All these three factors degrade the efficiency and limit the power level. So, after invention of power semiconductor devices these problems can be overcome. Consequently a large number of inverters are invented but key components in all these power electronic devices. Particularly in hybrid, electric, and fuel cell vehicles, the Insulated Gate Bipolar Transistors (IGBTs), freewheeling diodes and advanced power module technology are used. After that a Novel PWM scheme was invented for controlling the output of an inverter with improved fundamental component value[16]. The main advantage of this approach is that it adopts a consistent strategy for the entire range of modulation index i.e. it does not require any mode change and also causes exactly same number of switching per cycle. The appreciable improvement in THD in the lower range of modulation depth attracts drive applications where low speed operation is required.

## III. ADAPTIVE GAIN SCHEDULING

In control theory, gain scheduling is an approach to control of non-linear systems that uses a family of linear controllers, each of which provides satisfactory control for a different operating point of the system. One or more observable variables, called the scheduling variables, are used to determine what operating region the system is currently in and to enable the appropriate linear controller.

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A gain-scheduled controller is a controller whose gains are automatically adjusted as a function of time, operating condition, or plant parameters. Gain scheduling is a common strategy for controlling systems whose dynamics change with time or operating condition. Such systems include linear parameter-varying (LPV) systems and large classes of nonlinear systems. Gain scheduling is most suitable when the scheduling variables are external parameters that vary slowly compared to the control bandwidth, such as ambient temperature of a reaction or speed of a cruising aircraft. Gain scheduling is most challenging when the scheduling variables depend on fast-varying states of the system. Because local linear performance near operating points is no guarantee of global performance in nonlinear systems, extensive simulation-based validation is usually required.

### ADVANTAGES:

In this system, machine performance can be degraded by the dynamics of the substructure such as rotor, actuators, etc. which are not known completely at the time of controller design. This adaptive gain scheduling addresses this problem and exhibits performance close to the optimal design. This synthesis can be extended to guarantee performance in the face of parameter estimation and measurement errors.

### IV. SIMULINK MODEL

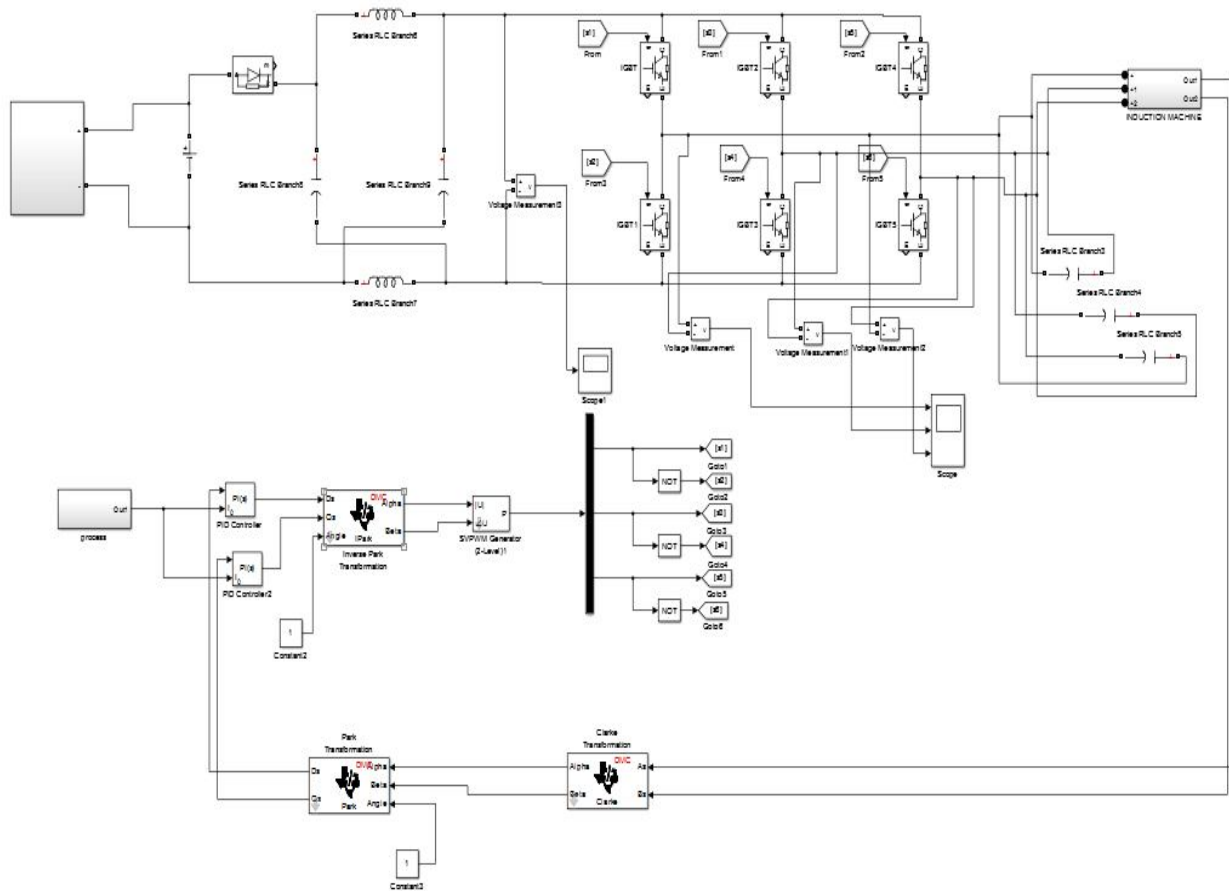


Fig. 2 Simulink Block diagram of Field oriented control

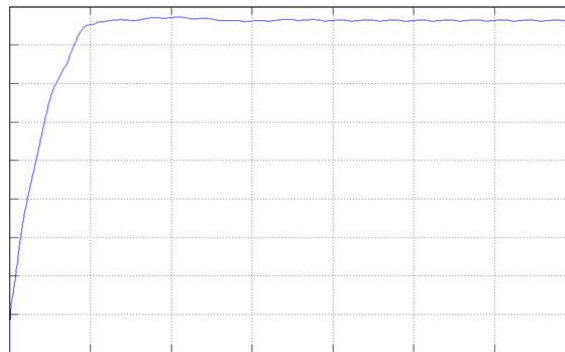
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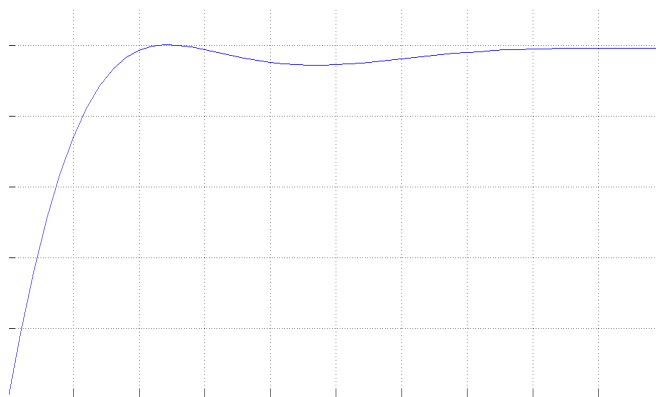
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This simulink model explains how the rectifier output is filtered via dc link and fed to the inverter. The output of inverter is given to the induction machine. The output rotor speed is then controlled using field oriented control. That is made through the adaptive gain scheduling approach.

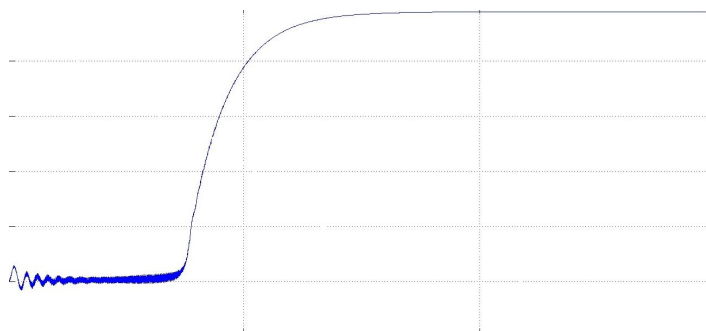
## V. EXPERIMENTAL RESULTS



(a)



(b)



(c)

Fig. 3. Simulation results (a) Output of Vienna rectifier (b) Gain scheduling result (c) Rotor speed of induction machine

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## VI. CONCLUSION

Hence VFDs provide the most energy efficient means of capacity control. Adding a variable frequency drive (VFD) to a motor-driven system can offer potential energy savings in a system in which the loads vary with time. This project explains the operating speed of a CEP motor connected to a VFD is varied by changing the frequency of the motor supply voltage. This allows continuous process speed control. The ability to adjust motor speed enables closer matching of motor output to load and often results in energy savings. The Vienna rectifier acts as a boost converter. Z source inverter acts as a buck boost inverter. Harmonics produce due to the usage of power electronic devices is eliminated by filters. The SVPWM used to generate signals for the inverter generates minimum harmonic distortion. Thus the proposed model is implemented in MATLAB/SIMULINK and the results have been analysed.

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