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High Starting Performance DC Motor

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Abstract

Crane or lifting machine is a tool that widely used in the container port at Dermaga Tanjung Perak Surabaya City, with series excited DC motor movement. The main functions of crane are to lift, move and discharge some goods from the origin place to determined place. The main composition of crane is electric motor as driver and gearbox as reduction of gear transmission and controller as the manager of electric motor speed. From three main components above, the component that needs serious treatment is the controller for the series excited dc motor. The stability control system of crane is the starting current at series dc motor. High starting performance dc motor of a crane with volt/hertz control requires rapid dynamics and precise regulation, that make the need of direct control is an urgent demand. Therefore, an independent control of torque and flux, which is similar to a separately excited DC motor is needed. Series DC motor has a high starting torque while separately excited DC motor can operate above the base speed in the starting current. Therefore, in this paper a high starting performance dc motor is suggested to run the series DC motor below base start. The Series DC motor direct control strategy is explained and a control circuit is proposed. A steady-state and transient analysis of the series dc motor is performed below and above base starting current.

Keywords: series DC motor, starting current, crane, volt/hertz Control.

1. Introduction

In spite of the development of power electronics sources, the direct current machine became more and power using battery system or for the electric traction in the multi-machine system too. DC motors are still widely used in industries and still play a significant role in modern industrial drives. Dc motor requires high starting current since starting torque at dc motor is very high. The high starting current of DC motor must be adjusted to a to provide easy controllability and high performance. The controllers of the high starting current that are conceived for goal to control the starting torque of dc motor to execute one variety of tasks, is of several conventional and numeric controller types, the controllers can be: variable control, bjth-bridge control, chopper control, two quadrant control and four quadrant control. The control a five in illustrated fig.1a, fig.1b, fig.1c, fig.1d and fig.1e.

The DC motor has a wide range of applications. Its constant speed operation (even under load variation and voltage fluctuation) and high efficiency (90-98%, the highest of all motors) make it most suitable for constant- speed, continuous-running drives. In addition, a unique feature of dc motors is not their power factor control capability. If the motor is overexcited, it draws leading reactive current which then can be used to compensate for a large number of induction motors that draw lagging reactive current. The leading reactive current drawn by the synchronous motor can improve the plant power factor and regulate the voltage at the receiving end of a long power transmission line, while at the same time such motors can act as prime movers for some drives in the plant.

The simple open-loop volt/Hertz (v/f) control method has been popularly used in low performance drives. Closed-loop with flux control, torque control, slip control, and angle control have been used where better drive performance is demanded, but these scalar control techniques have drawbacks due to non-linearity of the motor model and inherent coupling between the direct and quadrature axis quantities. This causes sluggish responses which are unacceptable for high-performance drive applications with fast and precise torque response. In order to achieve these required characteristics, several methods have been proposed to obtain fast response. The direct or field indirect control techniques are being accepted almost universally for control of drive. Direct control technique displays good performance for variable speed DC drive, where, both the phase angle and the magnitude of the current have to be not controlled. When referring the MMF wave of the stator current to this flux wave, it is realized that only the quadrature axis component of the MMF wave is contributing to the torque, whereas the direct axis component affects the magnitude of the flux. Hence, the stator current phasor is defined in a frame of reference defined by the time- varying field or in field coordinates. This indicates a close correspondence to the DC machines, with the direct axis component of the stator current vector being analogous to the field current and the quadrature axis component to the armature current [3]. Consequently, the decoupled direct control technique can be used so that the dc motor can achieve the dynamic performance capabilities of the separately excited DC machine, while retaining the general advantages of AC over DC motors. Direct Control has several advantages allowing easy control, fast torque response and accurate torque, speed or position control besides enabling the operation with a low load torque. Dynamic braking or regeneration is easily implemented. Also,the conventional stability problem of dc motor does not exist. The control can easily be designed to have four quadrants operation.. Therefore, the direct – indirect controlled dc motor can be used for high performance application. They have variable torque / speed characteristic and are used extensively in variable speed drives and they provide a high starting current and torque control over a wide range. The all methods of starting current control are normally simpler and less expensive than those of dc drives.

The series dc motor is proportional to the armature current and then the motor speed can be controlled by armature voltage. Also its speed direction can be reversed by reversing the armature voltage. In series DC motor, as the armature current, which equals the field current, changes with the load, the flux produced by the field winding also changes. Therefore, the torque developed by the motor is proportional to the square of the armature current as long as the motor is operating in linear region. Since the torque developed by a series motor is also proportional to the square of the applied voltage, its torque developed can be controlled by controlling the applied voltage. The typical speed characteristics of a series motor are inversely proportional to the armature current. This paper proposes a direct and indirect control dc motor drive system that merges the advantages of the separately excited DC motor and the series DC motor.

The basic configuration of the proposed direct and indirect control drive system consists of a dc motor fed by PWM voltage source converter and connected with the load as shown inFig.1. The optical incremental encoder mounted on the Rotor shaft indicates the actual position and the speed can be obtained. The drive is simulated using Matlab Simulink and results are obtained to show the transient and steady state performance of the motor. Fig.1 is showing starting current dc motor circuit in a model.

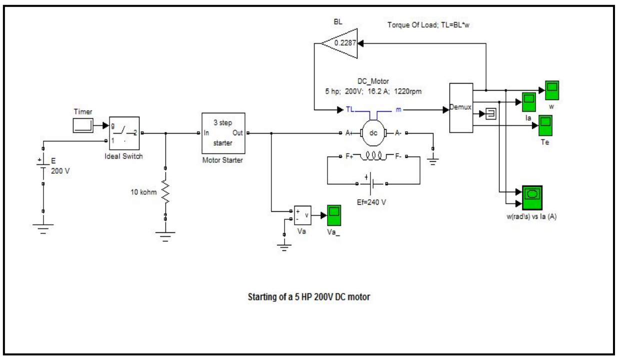

Fig. 1a. DC Motor With Variable Control Circuits Model

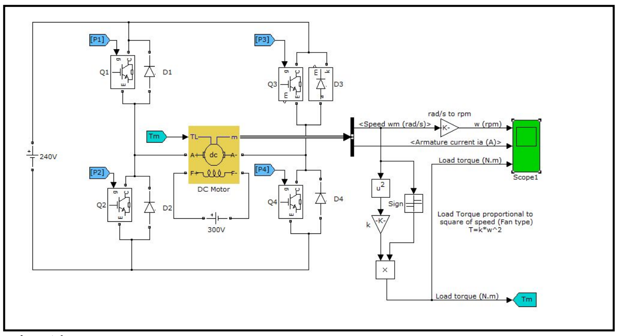

Fig.1b. DC Motor With Regenerative Control Circuits Model

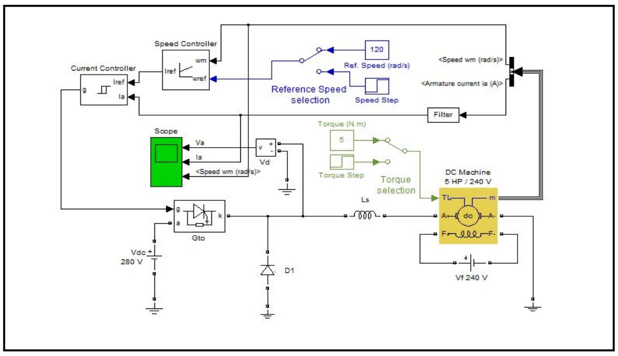

Fig.1c. DC Motor Drive With Chopper Fed Control Circuits Model

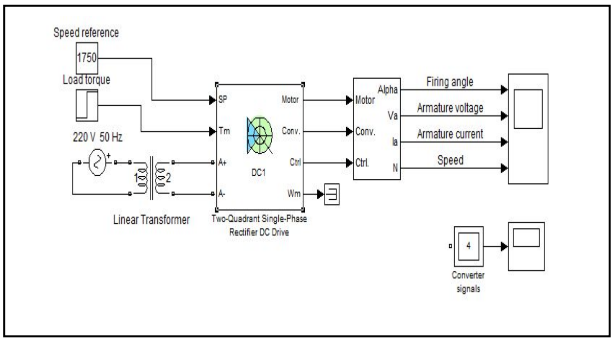

Fig.1d.DC Motor WithTwo Quadrant a Rectifier Control Circuits Model

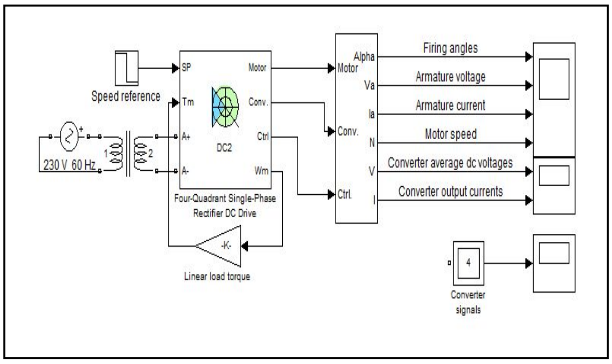

Fig.1e. DC Motor With Rectifier Control Circuits Model

Fig.1.High Starting DC Motor With Control Circuit Model

2. Dynamic Model

The direct-indirect control separates the torque and flux channels in the machine through its stator-excitation inputs. The current i_d is the stator current component in current to the machine is directly controlled such that i_q and i_d are independent variables. So that, the field or direct-axis current is made to be zero ($i_d = 0$), leaving only the torque or quadrature-axis current in place. Under this condition the stator voltage equation will be given by :

$$V_s = Vt - K\,\Theta_r\,\omega_r \qquad (1)$$

$$I_s = \frac{Vt - K\Theta_r\omega_r}{R_a} \qquad (2)$$

And The torque expression will be :

$$T_s = K\ \Theta_r I_s \qquad (3)$$

$$T_s = \frac{pz}{2\pi a}\ \Theta_r I_s \qquad (4)$$

$$T_s = A.q.C_1 \qquad (5)$$

Where

T_s is the crane load in Nm

A is the effective frontal area of the part under consideration in m^2

Q is the wind pressure corresponding to the appropriate design condition in N/m^2

C_1 is the shape coefficient in the direction of the wind for the part under consideration

I_s is series current in ampere

R_a is series armature in ohm

V_t and V_s is nominal voltage in volt

Because of the absence of d-axis stator current there is no reluctance torque and only the q-axis reactance is involved in finding the terminal voltage, i.e. there is no direct magnetization or demagnetization of the d-axis, only the field winding acts to produce flux in this direction. Thus, the torque response for field orientation is instantaneous and follows the commanded value of i_s exactly. This is the same as for a DC machine circuit in showed fig. 2a under constant terminal voltage operation has the torque and line starting current characteristics of fig. 2b, fig.2c and fig.2d.

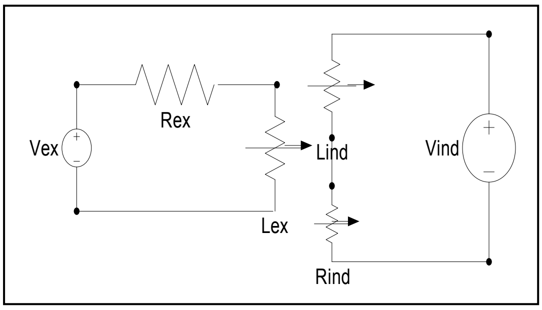

Fig.2.a. Series DC Motor equivalent circuit Model

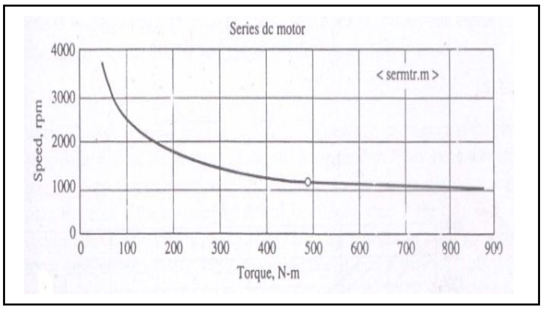

Fig.2.b.Series DC Motor Of Starting Torque Characteristic

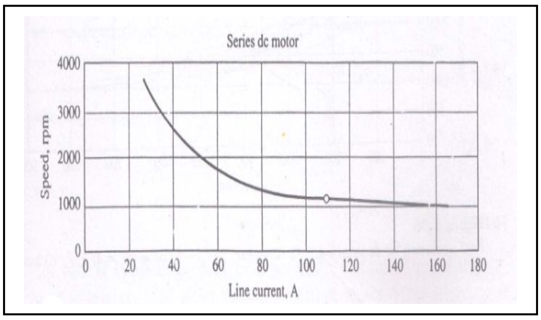

Fig.2.c.Series DC Motor Of Starting Current Characteristic

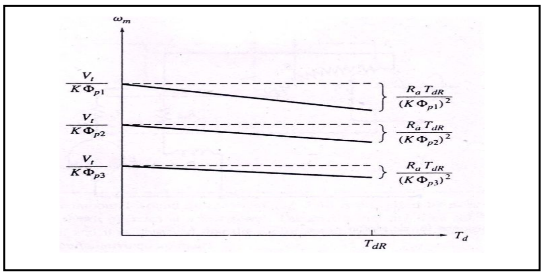

Fig.2.d.Series DC Motor Of Speed Characteristic

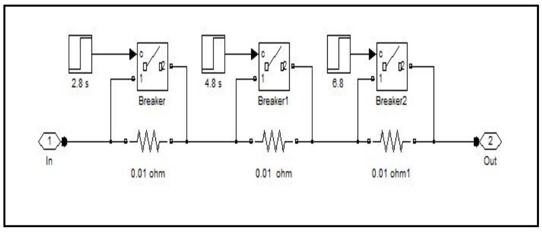

Fig.3a. Variable Regenerative Control Model

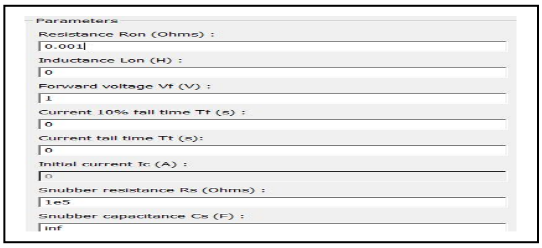

Fig.3b. BJT-H Bridge Control Model

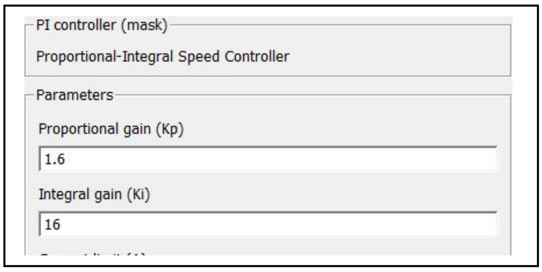

Fig.3c. Chopper Fed ontrol Model

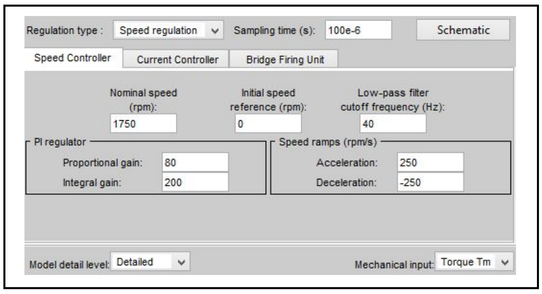

Fig.3d. Two Quadrant 1 Phase Rectifier Control Model

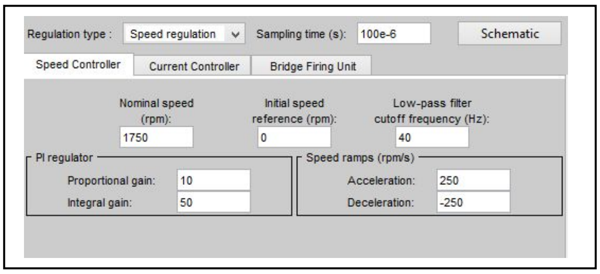

Fig.3e. Four Quadrant 1 Phase Rectifier Control Model
Fig.3. DC Motor With Controller Parameter Model

3. Operating Modes of High Starting Performance Drive

Fig.4 shows the Research result of the direct-indirect control system of the proposed performance high starting dc motor. The absolute value of starting current the dc motor is compared with the dc motor with different a controller to application dc machine at which the voltage reaches its maximum permissible

value. Accordingly, the field multiplexer determines the stator field current signal (Is) such that below the base

speed, the command signal of stator field current equals to the absolute value of the q-axis current (Iq), meaning that the dc motor acts exactly like a series dc motor. This is corresponding to operating starting current dc motor in Fig.4. Above the base speed, the field current predetermined from the command rotor current is compared with the actual field starting current fed from the motor, and the error signal passes through a direct - indirect controller that gives the required field voltage Vf so as to run the machine as a separately excited dc motor using field current weakening mode operation within the constant power region. This is corresponding to staring speed dc motor of Fig.5. The value of the field command signal depends on the Absolute value of the speed meaning that is completely Independent on speed direction. This means that two Quadrant and four quadrant drive using this scheme is available. The control drive system with both constant torque and constant - power operation is presented in Fig.3. Equation (1) to (3) can be arranged depending on the motor speed to develop the dc motor performance characteristics curves at the rated armature current as shown in Fig. 4. It is seen that the dc motor is driven in a way such that its characteristic is similar to the series DC motor before base speed and similar to the separately excited DC motor characteristics in the field- weakening region during constant power region.

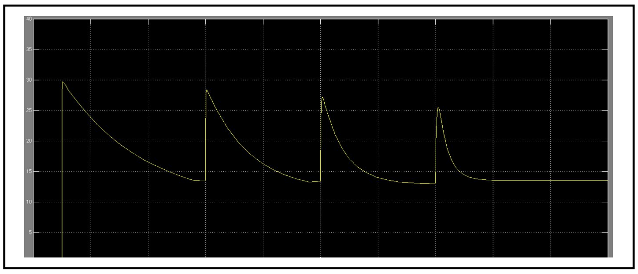

Fig.4a. The result of Starting Current dc motor with Variable Regenerative Control

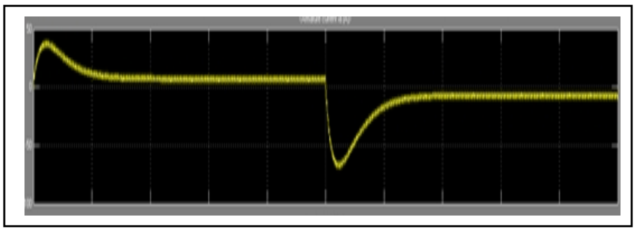

Fig.4b. The result of Starting Current dc motor with JT-H Bridge Control

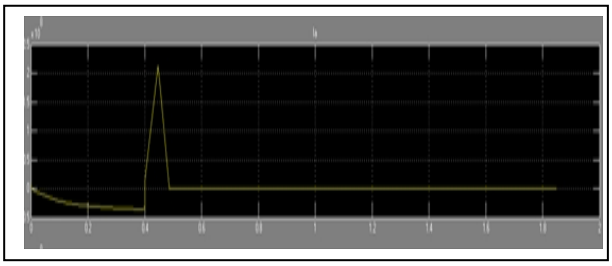

Fig.4c. The result of Starting Current dc motor with Chopper Fed Control

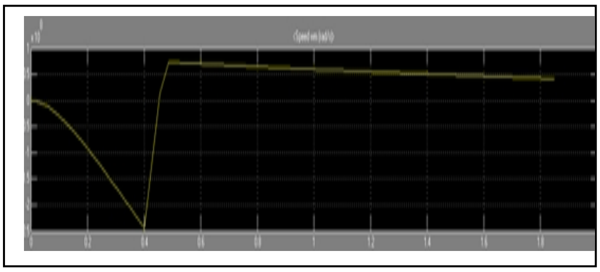

Fig.5c. The Result of Starting Speed dc motor with PI Control

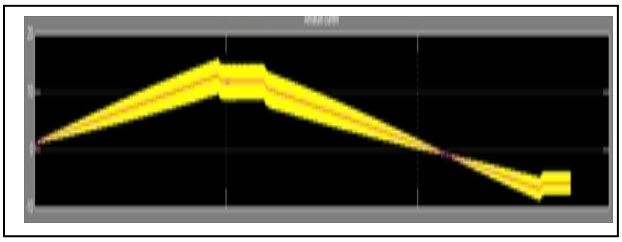

Fig.4d. The result of Starting Current dc motor with two Quadrant 1 Phase Rectifier Control

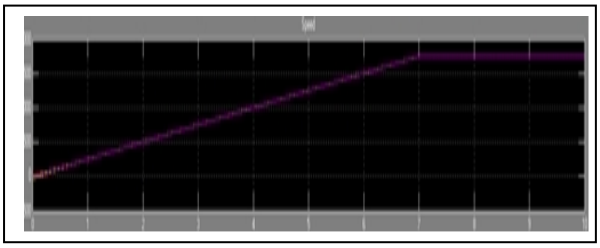

Fig.5d. The Result of Starting Speed dc motor with two Quadrant 1 Phase Rectifier Control

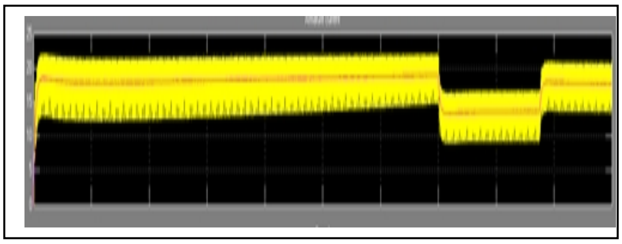

Fig.4e. The result of Starting Current dc motor with Four Quadrant 1 Phase Rectifier Control

Fig.4. The Research Result Of Starting Current DC Motor With Controller Model

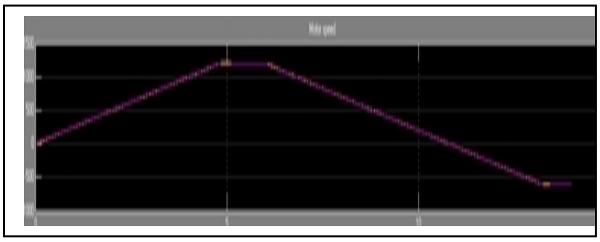

Fig.5e. The result of Starting Current dc motor with Four Quadrant 1 Phase Rectifier Control

Fig.5. The Research Result Of Starting Speed DC Motor With Controller Model

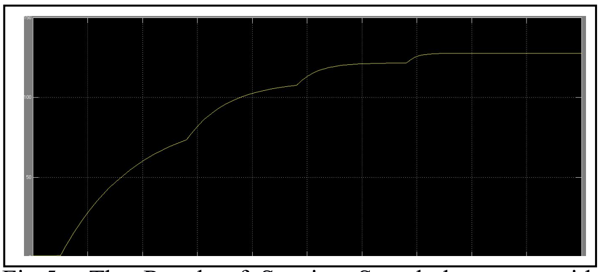

Fig.5a. The Result of Starting Speed dc motor with Variable Regenerative Control

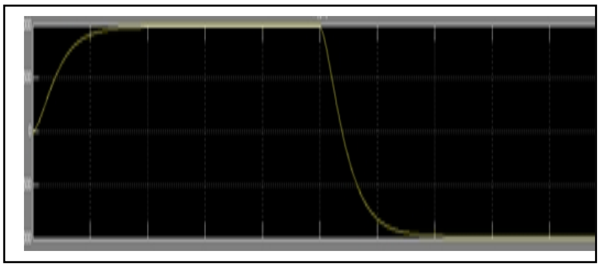

Fig.5b. The Result of Starting Speed dc motor with BJT-H Bridge Control

4. Transient Response

The Model depicted in Fig.1 has been simulated to conclude the transient response of the proposed drive. The starting current command signal is increased from 12,5 to 49 Ampere at time t_1= 0,1 to 0,5 sec. And so The speed command signal is increased from 750 to 1300 rad./ sec at time t_1 = 0,1 to 0,5 sec. Fig. 4 and Fig. 5 shows the instantaneous waveforms for a starting step current and starting step speed change below and above the starting dc motor such that before time t_1 the motor runs at rated load torque in the constant torque region. It is clear that the machine has a high starting current like a series dc motor, while current limiters have been adjusted to limit the field current at its rated value. Whereas after time $t_{1,}$, the starting current will increase about 35 % above the base current. Which will consequently lead to the decrease of the field current and hence the decrease of the torque about about 25 % below the full load value in order to maintain q-axis current at its rated value. The q-axis current is controlled to equal the rated current while the field current is determined to run the machine in the constant power region and therefore the current is decreased.

Name Of Motor	Driver	Power (HP)	Inertia(Kgm^2)	Torque (Nm)	Current (A)	Velocity (Rad/ second)
DC Motor with Variable Control Circuits	Variable Control Circuits Model	5	1	22	27	750
Speed Control Of a DC Motor using BJTH-Bridge	BJT – H Bridge	5	1	7	49	1000
Chopper Fed DC Motor Drive	DC To DC Chopper	5	1	7	32	1300
Two Quadrant Single Phase Rectifier DC Motor Drive	Converter	5	1	7	35	1000
Four Quadrant Single Phase Rectifier DC Motor Drive	Converter	5	1	10	12,5	1200

Table 1, The Research Of Result Performance DC Motor

5. Conclusion

In This paper, The Starting current of DC motor drive is controlled by a five type controller. According to the results of the computer simulation, the Four Quadrant single phase rectifier controller efficiently is better than the traditional a five type of controller. The Four Quadrant single phase rectifier controller is the best controller which presented satisfactory performance and possesses good robustness. That we close with the use of the Four Quadrant single phase rectifier for the performance of this controller in order to starting current control of series DC motor. Finally, the proposed a Four Quadrant single phase rectifier controller gives a very good results and possesses good robustness.

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Appendix

The Parameters of the 220 volt, 3000 watt DC Motor are :