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Optimization of Single Phase fed three phase VFD using ANN

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Abstract*: *Several applications in rural areas necessitates the use of single phase fed three-phase VFD's which need to consider certain constraints. These constraints are usually addressed by strictly de-rating the VFD considering only the DC bus voltage ripple. The other constraints like peak currents of the input diode bridge rectifier and beyond current rating of input terminal blocks in addition voltage ripple across the DC bus capacitor need to be considered for a finest performance of VFD which confines the output power capability to the single-phase rated value of the VFD. A novel motor q-axis current with ANN algorithm is introduced to overcome this problem which takes in to account of all the component stresses which need to be addressed. The simulation for the proposed model is done in MATLAB/Simulink environment. The analysis of average and ripple current controller of motor q-axis current and DC bus ripple voltage is done using the proposed methods.

Keywords* : *ANN,PSO ,VFD, q-axis average current, q-axis ripple current,

I. INTRODUCTION

Many Industrial applications for fixed speed of induction motor has been substituted with the Variable Frequency Drives with which the change in speed is possible by altering the motor input voltage and frequency. Though various technologies being followed to produce three phase power from single phase sources, VFDs are given the top priority compared to common technologies like static phase converters and rotary phase converters for their low capital cost and high reliability [1]-[3]. The two main units of VFD are Rectifier and Inverter. The Rectifier unit converts the AC input into pulsated DC which can be smoothened with appropriate filter circuit. The smoothened DC output from rectifier acting as input to the Inverter unit converts the DC into the required AC output.For the irrigation in the rural locations and the applications in remote areas like mining of oil from profound wells needs the three phase VFD fed with a single phase source [4], due to the non-appearance of three phase source in rural areas. There are certain boundaries that are desired to be faced with the single phase fed three phase VFD. The worth of RMS current input is twice with the single-phase supply related to the three-phase supply which primes to go beyond the current rating of the terminal blocks, peak and averagecurrent ratings of the diode rectifier in the input side and higher ripple current which primes the heating of the DC bus capacitor.

The harmonic distortion of the input current is also excess when single-phase input is given for three-phase inverters [5]-[10] which leads to the lesser system efficiency and power factor. The manufacturers usually adopt the method of derating the VFD which is mainly based on the ripple current capability of the DC bus capacitor [6]. The traditional frequency fold back method (FFB) which comprises of a simple PI controller in which the DC bus ripple voltage is used as a set point, which is proportional to the extreme acceptable capacitor ripple current classically at 100 Hz-120 Hz frequency and 60° C [7]-[10]. The FFB function gets activated when the ripple voltage of the DC bus surpasses the set value then the output frequency is condensed to limit the output power which eventually reduces the DC bus ripple current with in the permissible value.

II. BACKGROUND

Though the traditional FFB method is simple to implement, the goal of reducing the other component stresses is not met since the current rating of terminal blocks of the VFD can exceed the DC bus capacitor voltage value. Also certain factors like deterioration of capacitor, frail AC source reduces the average voltage of DC bus voltage results in the increment of load current which in turn effects the drive's output power. To overcome these limits usually the VFD manufacturers follow three techniques.

First one is the derating technique. While derating the VFD manufacturers calculating the drive's rating, verify the core temperature of the capacitor with the experimental tests which mainly hinge on of the DC bus capacitor ripple current.Second one is adding components to the existing VFD which does not encompass much alterations in hardware [11]-[12]. It is easy to implement the de-rate technique as it doesn't require much modifications in the hardware [2]–[8]. Fig 1 represents the low cost hardware circuit comprising of bidirectional switch with a common emitter arrangement.

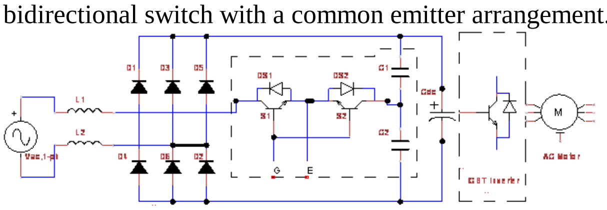

Fig:1 A low cost single-phase active front-end circuit [15]

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Due to the introduction of this bidirectional switch the current rating is reduced to 35% . In spite of its cost and size , this topology carries the rated power without the need of derating. In most cases, the standard phase-loss monitoring and protection built in may be similar to the control algorithm. However the reliable performance of the drive can be achieved without much derating.

Third one is to develop the firm control-algorithm system blended with the derate choice to improve the performance of the VFD.

III. CONTROL ALGORITHM

The Control algorithm that is developed by making use of the q-axis current which is the resultant of the output current. It is observed that[13] there is a relation between q-axis and the input current ripple and also there is a relation between ripple voltage of DC bus and q-axis current .The flow chart of current control of q-axis is shown in Figure2. Here the two components i.e., the average current and ripple current of q-axis are introduced. In the traditional FFB method though the reduction of voltage ripple of DC bus is done by reducing the frequency but it has no effect of reducing the input current and other vagaries modelled by various external factors [13].

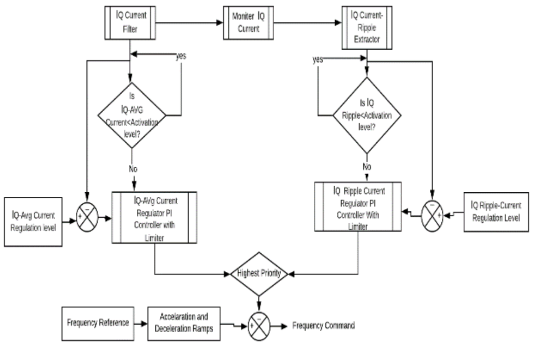

Fig.2 Flowchart for the control algorithm of q-axis current

The flowchart shown in Figure 2 consist of two PI controllers. The q-axis average current is regulated by the first controller which is represented by $I_{Q\text{-}AVG}$ and the q-axis ripple current is regulated by the second controller which is represented by $I_{Q\text{-}RIPPLE}$ .In the $I_{Q\text{-}RIPPLE}$regulator, the ripple current regulator gets activated if the measured amplitude of $I_{Q\text{-}RIPPLE}$ current is superior than the triggering level and the error is been given to the corresponding PI controller which generates the low frequency command. One thing that should be ensured is the output of PI controller is within the triggering and deactivation levels, so as to avoid the high frequency swings which results in high input diode and capacitor current. [14]-[16]. The value of $I_{Q\text{-}RIPPLE}$ current regulator is based on the ripple handling capacity of the DC bus capacitors and the peak current rating of the input rectifier diodes. Whereas in the $I_{Q\text{-}AVG\ current}$ regulator, the average current increases due to increment of the load torque endlessly afar from the single phase rating of the rectifier diode which results in the activation of $I_{Q\text{-}AVG}$ current regulator and the error is granted to the corresponding PI controller which generates the low frequency command.

IV. ARTIFICIAL NEURAL NETWORK

Neural networks are one of these phrases this is getting elegant within the new technology of the era. Most humans have heard of them, however only a few recognize what they're. The 'neural network' is a genetic word, and what we refer with as neural networks have to truly be termed as Artificial Neural Networks (ANNs). An actual neural network is a group of neurons.An ANN is basically a collection of appropriately interconnected non-linear factors of quite simple forms that own the capacity of mastering and version. These systems are considered through their topology, the way in which they connect with their situation, the manner in which they are educated and their ability to procedure information. An alternative to "fuzzy" regulators in many instances, neural controllers' percentage the need to replace hard controllers with smart controllers on the way to boom manipulate first-rate. A feed-forward neural network works as a compensation signal generator.

V. RESULTS AND ANALYSIS

In this section results were from a 0.75-hp,230-V, three-phase VFD supplied with the single phase AC source for the pump application.The particulars of the values of parameters is given in the table1.Comparision of the proposed models is done with the motor q-axis current method and the conventional DC bus voltage ripple foldback method[15]. The simulation results were attained for a period of 50 seconds. The results revealed in Figure 3 describes the DC bus voltage, output frequency, input current , output power. The q-axis based FFB method is shown in Figure 4.

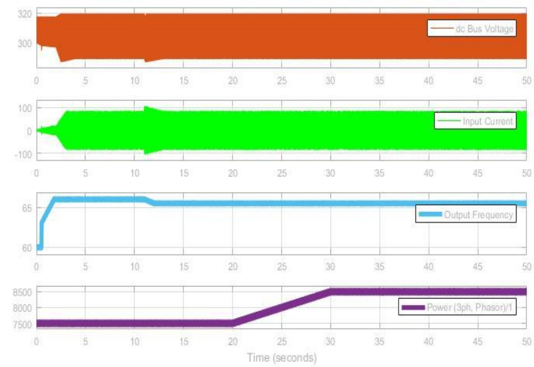

Figure 3. Simulation results of voltage ripple of DC bus based FFB [15] with time scale (5sec/div)

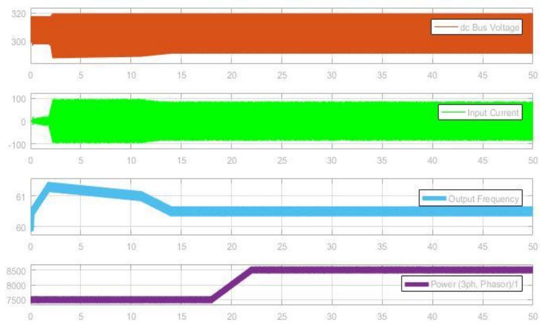

Figure 4. Simulation results for the q-Axis Current based FFB process [16]. Time scale 5sec/div

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From Figure 3 when the ripple voltage of the DC bus value surpasses its set value, the FFB process is activated and the output frequency is mitigated until the ripple voltage of the DC bus is regulated to its specified value and the steady state output power is 0.47hp which is higher than its single phase rating of 0.33hp.If the drive is loaded to a value superior than its single phase rating, at the interval 20sec,there is an increase of output power and hence increase in the value of DC bus voltage ripple value which switches the conventional frequency fold back method, which results in the reduction of frequency.In Figure 4, when the drive is loaded than its one phase rating at the interval of 17.5 sec, there is an increase in the power output, which increases the DC bus ripple voltage value and also there is an enhancement in the q-axis current since there is a correlation between the DC bus ripple voltage and q-axis current values. Hence the q-axis current based FFB method is switched since the q-axis current value is higher than its set value, which reduces the output frequency and regulates the output power and it is observed that there is decrement in the input current which is with in the specified limits unlike the traditional FFB method.The results shown in Figure 5(a)&(b) determine the motor q-axis ripple and average current methods respectively.

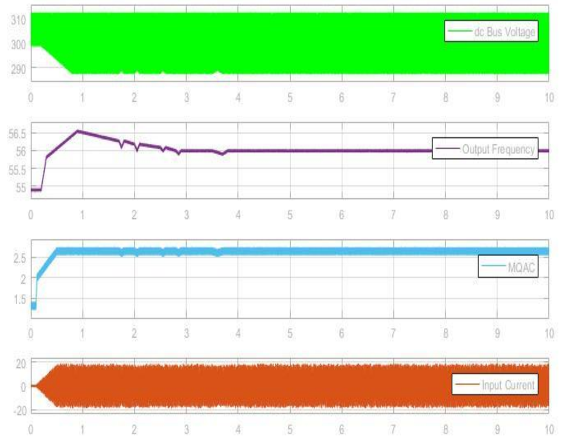

Figure 5(a) Simulation results of q-axis ripple current method based frequency fold-back [16] for 10(sec)

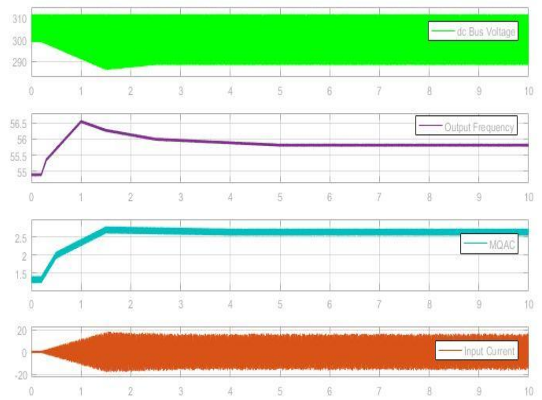

Figure 5(b) Simulation results of q-axis average current method for frequency fold-back [16] for 10(sec)

When the q-axis ripple current value is greater than its set value ,the PI controller of q-axis ripple current gets triggered and the output frequency oscillates for a short period as shown in Figure 5(a)and these oscillations are within the hysteresis band and the output frequency is steadily condensed until the DC bus capacitor and output power are within the particular values ,resulting in 0.37hp of output power and in Figure 4(b) 0.31 hp of output power is obtained by average current of q-axis method whose value is nearer to the desired rating of 0.33hp.

`Figure6&7 determines the performance analysis of $I_{Q\text{-Ripple}}$ method and $I_{Q\text{-Average}}$ methods in addition with speed and torque control for 50 sec respectively. It is observed that the ripples in output frequency has been reduced and also it attains the steady state in lesser than 3 sec.

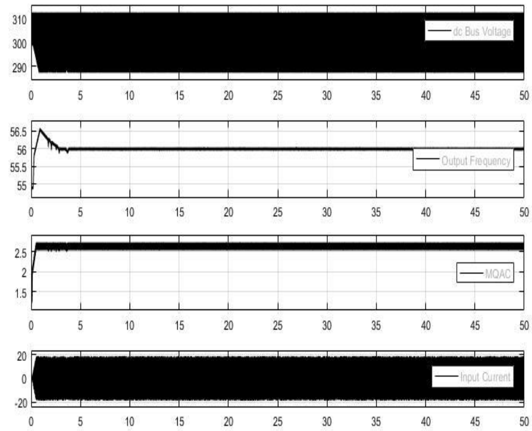

Figure 6(a)Simulation results of $I_{Q\text{-Ripple}}$current method [16]

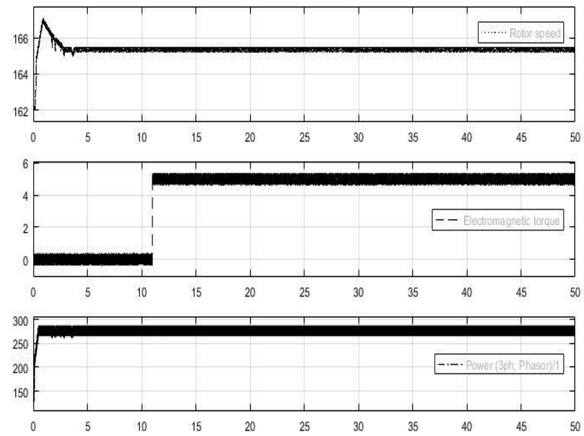

Fig 6(b) Speed and torque control

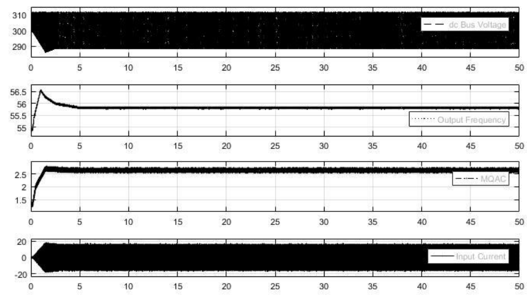

Figure 7(a)$I_{Q\text{-Average}}$ current method with 50sec for output frequency and MQAC

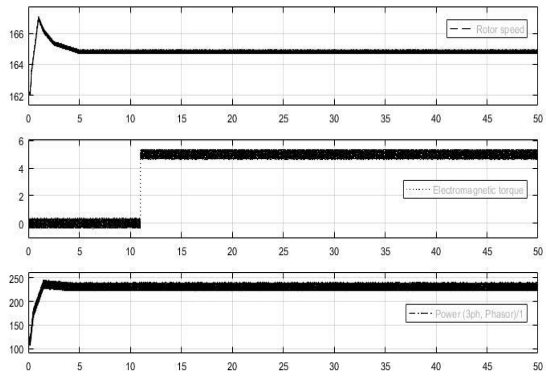

Figure 7(a) shows the simulation results of MQAC method [16] with IQ-Average current method with 50sec with output frequency and MQAC Figure 7(b) shows the speed and torque control.

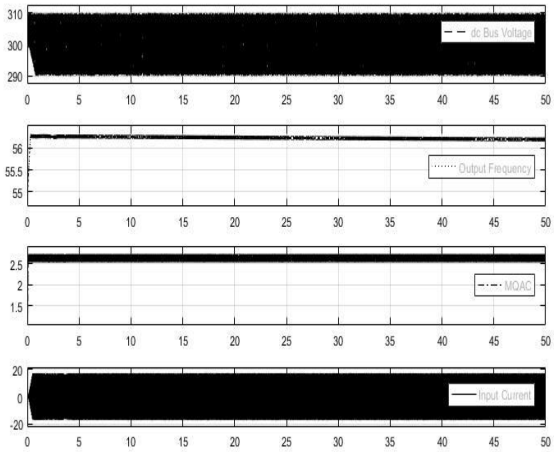

Figure 8(a)Simulation results using PSO

Figure 8(a)and 8(b) determines the results of the STP-PSO framework [17] in addition with speed and torque control from which it is observed that output frequency reached the steady state value at a value almost nearer to 1 sec. Figure 9 represents the simulation results using ANN(Artificial Neural Network) from which it can be analyzed that the output frequency has reached the steady state value at around 0.5 sec which is much less time than that of STP-PSO .

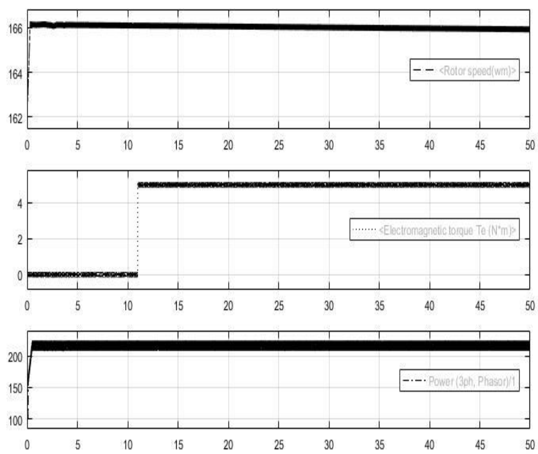

Figure 8(b) Speed and Torque control

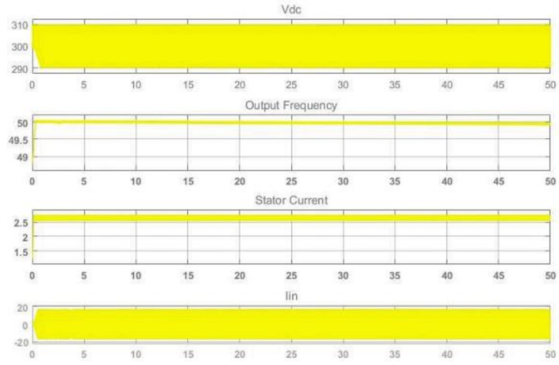

Figure 9 Simulations results using ANN

Table1 represents results of output power for single phase rating of three phase VFD using various techniques. It is observed that ripple voltage and RMS input currents are further reduced using the ANN algorithm which shows the mitigation of all the component stresses and in addition to that the output frequency has reached to the steady state value in less than 1sec which is not the case in other methods mentioned in the paper.

Table1 Pumpimg application results for different techniques[16]

Steady State Values	V_{dc} (V)	I_{INPUT} (Peak-Peak) (A)	I_{INPUT} (RMS)	Motor Speed (Per Unit)	POUTPUT In hp
Voltage ripple of DC bus technique [15]	28.80	39.90	5.70 A	0.940	0.470 hp
I_Q Ripple technique [16]	25.30	34.10	4.90 A	0.860	0.370 hp
I_Q average technique [16]	23.50	30.50	4.30 A	0.800	0.310 hp
PSO[17]	**21.50**	**28.00**	**3.89**	**0.750**	**0.290 hp**
ANN	**19.4**	**24.3**	**3.20**	**0.59**	**0.22hp**

VI. CONCLUSION

The q-axis current of the motor (M-QAC) with particle swarm optimization technique and Artificial Neural Network is carried out for mitigating the strain over diverse components of single phase supplied three phase VFD. The fact associated with the several component pressures of the drive which comprises of capacitor deterioration, vulnerable AC system, stress over the input diode and terminal blocks in addition to the heating up of the capacitors due to the greater ripple voltage across the DC bus capacitor is considered. By the usage of the proposed STP-PSO and ANN schemes, the pressure over the AC motor and further parts of VFD has been lessened to enhance the VFD operation correctly. The proposed method is intended to be exploited as an additional characteristic as a safety for the drives which is more advantageous in an excellent manner for the same energy derating while in comparison to the drives operating with a safety characteristic based totally on dc-bus-voltage-ripple.

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