International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

Direct Power Controller Converter for Pulse Width Modulation

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***Abstract*— Shunt active power filters(SAPFs) are used to compensate current harmonics of non-linear loads to perform reactive power compensation and to balance the imbalance currents. The non-linear loads in electronic devices causes distortion of power quality. In order to decrease the distortion and to improve the power quality, Direct Power Control (DPC) is used. In a Direct Power Control technique, instantaneous active and reactive power are kept within a hysteresis band. In order to increase the performance, the model predictive DPC along with Fuzzy logic set and Artificial neural network is combined and simulated. This decreases the duration of downshift in active power. DPC plays vital role in reducing power fluctuations and thus decreases the total harmonic distortion. The total harmonic distortion is reduced. Comparison of parameters is discussed. To prove the performance of the control system and to validate the approach simulation is carried out in Vivado.**

Keywords—Shunt active power filter; Vivado; MP DPC; ANN DPC

I. INTRODUCTION

In our day today life, we use electronic devices on a large scale. The proliferated use of non-linear loads in the household and industries are distorting the power quality of the grid significantly. The voltage fluctuations happening in the domestic and industrial sector tends to reduce the duration of the electronic devices. In order to rectify the voltage fluctuations, we have been using stabilizers, inverters, UPS for various devices. In stabilizers, inverters, and UPS, we use active filter, that can reduce the voltage fluctuation. The consequences of this impure sine wave of the current are increased line losses, saturation in the core of distribution tranformer cause of interference in the nearby communication system.

The active filters have been preferred from the passive filters as they are free from resonance, tuning difficulty, and need for the parameter change with changing load. But the efficiency of active filters is low when compared to Shunt Active Power Filter. For the control of the inverter which is used to produce canceling harmonic components of the grid current, the DPC is used as it shows superior performance in terms of dynamic performance and absence of current control loops in the control structure**.** Every efforts will be directed towards developing a control strategy that achieves the best results by reducing current THD and power ripple [8]. Due to the applications of a large number of nonlinear loads, smart appliances and renewable distributed generations, harmonic compensation has become more and more important in the distributed generation systems in order to guarantee its stability with a correct and efficient operation. Conventionally passive filters have been applied to reduce current harmonics and to enhance the load power factor.

Nevertheless, in practical applications, these filters display several drawbacks such as aging and tuning problems, series and parallel resonance, bulk passive components and low flexibility in the compensation characteristics. These drawbacks lead to a strong limitation in the selection and choice of passive filters. In order to increase the efficiency of the Shunt active Power filter we use the model predictive control In order to control the voltage fluctuations, we can use the Direct Power Control so that Pulse width Modulation can be done easily [5]. A control strategy that achieves the best results by reducing the THD is carried out. In a direct power control technique instantaneous power errors of active and reactive power components are kept within a fixed hysteresis band. An effective procedure to develop a control strategy for control of SAPF based on model predictive direct power control has been simulated. Researchers have moved towards active filtering because active filters are capable of compensating the current harmonics in addition to the reactive power and load imbalance.

The shunt active filter injects a current such that it cancels out the harmonic component in the grid current. The whole combination of the filter and the non-linear load draws a sinusoidal shape of current. The converter used here as an active filter operates as a voltage fed PWM inverter from a self-assisting DC bus. The structure of the active filter is lighter, cheaper, and it can also be extended to a multistep and multilevel control to upgrade the performance [1]. Speed performance of new components and flexibility inherent of all programmable solutions gives today many opportunities in the field of digital implementation for industrial control systems. This is particularly true with hardware solutions such as field programmable gate arrays (FPGAs), reflected a right solution to enhance the performance of the controllers. Effectively, these generic components combine between lowcost development (due to their re-programmability), use of suitable software tools, and extra important integration density. Actually, FPGAs have already been used with success in many different electric system applications such as a power converter control (pulse width-modulation (PWM) inverters) multilevel converters and electrical machines control. This is because an FPGA-based implementation of controllers can efficiently answer current and future challenges of this field.

II. LITERATURE REVIEW

Abinash rath [1]The control techniques like the model predictive and the algorithm based direct power control are well-known control methods for the control of active front end rectifiers. The ST-DPC is designed considering certain specific values of the system parameters. The switching vector is decided considering only the sign of the error ignoring the magnitude of the demand. The MP-DPC belongs to the predictive family of controllers in which the behavior of each switching vector is predicted analytically over an '*N*' step horizon, where '*N*' is the number of possible switching vectors. Modulation is another approach to improve the output voltage waveform of the inverters [2]. PWM and SVM methods in the voltage source converters (VSC) is now a generally accepted concept to derive an AC output voltage with full controllability in terms of frequency, amplitude and phase, but relatively low DC voltage controllability. Voltage reinjection is a practical solution to improve the quality of the output voltage in the high power series inverters. Novel reinjection structure in the two series DC/AC converters is proposed to increase the output voltage levels. The proposed voltage reinjection structure generates a nine voltage levels waveform to inject into the main DC-link voltage of the 12-pulse VSI. Also, the proposed configuration by using less number of the semiconductor elements than another structure's has better output voltage quality, and the losses and stress of the reinjection switches are decreased in high power application. The high switching frequency increases the stress on switches and switching losses especially in the high power applications [2]. The increase in various types of loads and their sudden connection and elimination from the distribution line is unpredicted. The PV fed filter can be utilized to compensate the voltage related problems and also it can help to maintain the supply across the load when there is no power supply [3]. The specific model is designed to keep the voltage across the dc link capacitor constant for efficient operation of the filter. The filter can boost up and down the voltage as and when required and also provide the necessary voltage to the distribution line for forcing the load voltage to be balanced.The conventional direct torque control loop is based on the switches' controllers. This method makes many fluctuations in the speed performances, the flux evolution, and the electromagnet torque progress [4]. The conventional direct torque control drawbacks are resolved by improving this control loop using the fuzzy control topology. The dual stator induction machine consists of two three phase stator windings, the stator ''1'' and the stator ''2'', and a common squirrel-cage rotor winding. Speed performance of new components and flexibility inherent of all programmable solutions gives today many opportunities in the field of digital implementation for industrial control systems [5]. This is particularly true with hardware solutions such as field programmable gate arrays (FPGAs), reflected a right solution to enhance the performance of the controllers. Effectively, these generic components combine between low cost development (due to their re-programmability), use of suitable software tools, and extra important integration density. an effective procedure to design and simulate DCC for a SAPF is presented.

The approach is based on the replacement of switching table and hysteresis controllers by a vector modulator and PI controllers to ensure operation at a constant switching frequency [6]. Active filters have several advantages over traditional compensation methods, as they adapt to changes that may occur in the load, minimize the possibility of resonance occurrence and can balance the currents in the line in the case of unbalanced loads. The aim was to eliminate the pulse width modulation block and internal loops of the controlled variables by replacing them with a switching table whose inputs are the errors between the reference values and the measurements [6]. Instead of the traditional PI controller, ANN controller is used to reduce the peak overshoot and ripple in active power [7]. The Switching table based ANN controller for the direct power control (DPC) is simulated. ANN controller achieves excellent transient performance under unity power factor operation without abnormal instantaneous reactive power fluctuations.

Direct Power Control technique of the PWM rectifier, improves the performance of PWM converter, called Direct Power Control Based on Artificial Neural Network (ANN), applied for the selection of the optimal control vector [8]. DPC-ANN ensures smooth control of active and reactive power in all Sectors and reduces current ripple. This paper proposes an approach intelligent technique of PWM rectifier such as artificial neural network (ANN), applied in switching select voltage vector optimal [8]. Direct virtual torque control (DVTC) strategy for synchronizing double-fed induction generator (DFIG) with grid and voltage oriented control (VOC) for controlling voltage of link capacitor is done. All strategies are implemented on artificial neural network (ANN) controller to decrease the time of calculation in comparison with the conventional DSP control system[9]. The essence of three strategies is selection appropriate voltage vectors on the rotor side converter. The instantaneous active and reactive powers, directly controlled by selecting the optimum state of the converter, are used as the PWM control variables instead of the phase line currents being used. The proposed fuzzy logic controller presents the advantage that is based on linguistic description and does not require a mathematical model of the system [10]. The controller ensures a good regulation of the output voltage, and guarantees the power factor close to one. The simulation and experimental results show that the designed fuzzy controller has a good dynamic behavior, a good rejection of impact load disturbance [10].

- Seven fuzzy sets for each of the two inputs;
- Triangular membership function;
- Fuzzyfication using continuous universe of discourse;
- Defuzzyfication using height method.

III. METHODOLOGY

The three phase voltage is fed to the 3/2 transformation module and it converts the voltage received to equivalent voltage and current units using resistor and inductor modules. Calculation of P and Q and the sector is done further, where P denotes the instantaneous active power and Q denotes the instantaneous reactive power. Three phase voltage is transformed to two phase voltage and is given to the p and q Calculation and after the p and q calculation the output is

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

being given to the Fuzzy Logic set and another output is also given to the artificial neural network. The Fuzzy Logic network analysis the weight and gives it to the model productive based direct power control. The model predictive based direct power control gives the output to the artificial neural network and in the artificial neural network the comparison of instantaneous active power with the reference instantaneous active power and instantaneous reactive power with the reference reactive power. The value is calculated and it is given to the shunt active power filter. The shunt active power filter performs the operation such that a stable power generation is done.

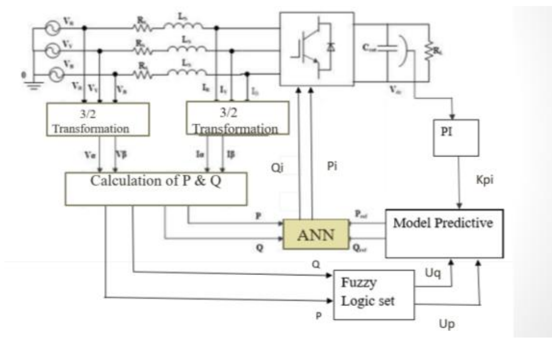

Fig 1 Direct power control based on Model predictive with Fuzzy logic controller and Artificial neural network

A. 3/2 transformation

3/2 transformation is the process where three phase voltage is converted to two phase for the smooth working of the device The 3/2 transformatiom of the voltage and current is done by the following equation:

$$V\alpha = \sqrt{\frac{2}{3}} * [V_a-(1/2)V_b-(1/2)V_c]$$

$$V_\beta = \sqrt{\frac{2}{3}} * [\sqrt{\frac{3}{2}}V_{b-} \sqrt{\frac{3}{2}}V_c]$$

$$I\alpha = \sqrt{\frac{2}{3}} * [I_a-(1/2)I_b-(1/2)I_c]$$

$$I_\beta = \sqrt{\frac{2}{3}} * [\sqrt{\frac{3}{2}}I_{b-} \sqrt{\frac{3}{2}}I_c]$$

B. Calculation of P & Q

The instantaneous active and reactive power is calculated by the following equation:

$$P= V_\alpha * I\alpha + V_\beta * I_\beta,$$

$$Q= V_\beta * I\alpha - V_\alpha * I_\beta$$

C. Fuzzy Logic controller

The instataneous active and rective power is then given to the Fuzzy logic controller and the Artificial neural network(ANN). These normalized values of the slopes of active and reactive power are divided into 4 fuzzy sets i.e. Positive high 50 to 100, positive low for the range of 0 to 50, negative low for 0 to -50 and negative high for the range of -50 to -100 [1].

The fuzzy logic controller calculates the value of Up and Uq by the following equation:

$$Up=f(P) = \Sigma(i=1 to\ n)\ Wp(i)*u(i), u(i)=P$$

$$Uq=f(Q) = \Sigma(i=1 to\ n)\ Wq(i)*u(i),\ u(i)=Q$$

D. Model predictive based direct power control

The MP-DPC belongs to the predictive family of controllers in which the behavior of each switching vector is predicted analytically over an 'N' step horizon, where 'N' is the number of possible switching vectors. The best suitable vector is selected by minimizing a cost function which consists of the differences between the demand and the predicted future values of the control variable. The switching vector which produces the least difference between the reference and the predicted control variables is selected. Compensation for the control delay is also provided to improve the accuracy in the vector selection process. The calculated values from Fuzzy logic controller is the given to the Model predictive based direct power control, where the values of P_{ref} and Q_{ref} is calculated :

$$P_{ref} = (P_{ref} -1)+Kpi*(e(k)-e(k-1)+Kpi*e(k) +Up$$
$$Q_{ref}= (Q_{ref} -1)+Kpi*(e(k)-e(k-1)+Kpi*e(k) +Uq$$

E. Artificial neural network based direct power control

The value calculated by the Model predictive based direct power control P_{ref} and Q_{ref} is given to the Artificial neural network(ANN). The Artificial neural network compares the value of instantaneous active power 'P' obtained from 3/2 trensformation with the 'P_{ref}', value obtained from Model predictive based direct power control and instantaneous reactive power 'Q' obtained from 3/2 transformation with the 'Q_{ref}', obtained from Model predictive based direct power control. The Output of the Artificial neural network(ANN) P_i and Q_i is calculated by the following equation:

$$Pi = (1/n) * \Sigma(i=1 to\ n)(P-P_{ref})$$

$$Qi = (1/n) * \Sigma\ (i=1 to\ n)(Q-Q_{ref})$$

The values obtained from the Artificial neural network(ANN) is given to the Shunt active power filter(SAPF) where the required power is given so as to maintain a stable power generation. The load resistance R_L of the circuit is calculated by :

$$R_L = V_{dc}\text{^}2/(3*P)$$

IV. RESULTS AND DISCUSSION

The simulation of Model predictive based Direct power control shows that for every 5ns output power, there is an downshift which means that for 100ns range the output is delivered for 50ns and downshift occurs for 50ns. The simulation proves that the efficiency of the system is only 50%.

The simulation of Artificial neural network based Direct power control in vivado shows that for every 10ns output obtained there is a downshift occuring for 10ns which means that for 100ns range 50ns output is obtained and 50ns downshift occurs. The simulation proves that the Artificial neural network based Direct power control has an efficiency of only 50%.

The simulation of combination of Model predictive based direct power with Fuzzy logic controller and Artificial neural network based Direct power control shows that for every 100ns range, the power delivered is for 70ns and the downshift occurs for 30ns. The simulation proves that the proposed method has an efficiency of 70%.

The Total harmonic distortion(THD) value obtained from the Model predictive based direct power control is 21.04%. The value obtained is higher and so we switch to an alternative method that is more efficient and accurate.

The Total harmonic distortion(THD) value obtained from the Model predictive based direct power control is 10.14%.

The Total harmonic distortion(THD) value of Model predictive with Fuzzy logic controller and Artificial neural network based Direct power control is calculated and the value obtained is 5.75%.. The value obtained proves that the proposed method is far more efficient and the harmonic distortion is less when compared to Model predictive based Direct power control and Artificial neural network based Direct power control

TABLE I.
COMPARISON OF MODEL PREDICTIVE AND ANN BASED DPC WITH THE COMBINATION OF THE THREE

Factors	**MPC DPC**	**ANN DPC**	**Combination**
Output	**5ns**	**10ns**	**70ns**
Downshift	**5ns**	**10ns**	**30ns**
Efficiency (100ns)	**50%**	**50%**	**70%**

The comparison shows that by using the Model predictive with Fuzzy logic controller and Artificial neural network we can generate a stable power, which will increase the durability of the devices.

TABLE II.
COMPARISON OF TOTAL HARMONIC DISTORTION

Power controller	**THD**
Model Predictive based Direct power control	**21.04%**
Artificial Neural Network based Direct power control	**10.14%**
Combination of Model predictive with Fuzzy logic Set and Artificial neural network	**5.75%**

CONCLUSION

By using the DPC, we can control the fluctuations within an electronic device in an efficient way. The model predictive based DPC with Fuzzy logic Control and ANN based DPC, makes the system more convinient to reduce the Total Harmonic Distortion (THD). The excellent transient performance under unity power factor operation without abnormal instantaneous reactive power fluctuations can be obtained . The Model predictive with Fuzzy logic controller and Artificial neural network based Direct power controller generate a stable power, which will increase the durability of the devices. The controller ensures a good regulation of the output voltage, and guarantees a better power factor . The current THD and power ripple reduction helps to increase the efficiency of the electronic devices. The proposed digital implementation achieves a valuable compromise between good performance and easy hardware implementation, with a minimum execution time and low resources utilization

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