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Research Article / Araştırma Makalesi

MFLC-PI CONTROLLED TWO LEVEL INVERTER BASED D-STATCOM FOR WIND ENERGY SYSTEMS

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ABSTRACT

Improving power quality which is an important concept in wind energy systems, Static Synchronous Compensator (STATCOM) has begun to be used instead of traditionally used static compensators and fixed mechanical switched capacitor groups. One of the Flexible Alternating Current Transmission System (FACTS) devices used to improve power quality is STATCOM device. STATCOM devices used in energy distribution systems are called Distribution STATCOM (D-STATCOM). D-STATCOM used to improve the quality of power in distribution systems is an inverter based device. For the control of the D-STATCOM device is usually performed PI controller with fixed parameters. In this study, D-STATCOM device has a two level voltage source inverter structure in wind energy distribution systems. Indirect current control method based on synchronous reference frame theory is used to produce gate signals for inverter. For control of these currents, parameters of the PI controller determined by a Modified Fuzzy Logic Controller (MFLC) which is called PI with modified FLC (MFLC-PI) is proposed for D-STATCOM. The proposed controller and D-STATCOM topologies for wind energy distribution systems are simulated in Matlab/Simulink environment.
Keywords: D-STATCOM, wind energy, FLC, MFLC-PI.

1. INTRODUCTION

One of the important renewable energy sources is wind energy. Wind energy produce energy from wind power [1]. These generators need to be continuously controlled and adjusted due to changes in wind speed. At the same time, these sources also harmonics. Stand-alone wind turbine systems require excitation capacitors and the generator that it has is also an electric machine [2]. So the system itself is already a harmonic source. In addition, when the load-side distorters are added, the system voltage and current are deteriorated and have a non-standard power grid. FACTS devices are used to eliminate these problems [3].

One of these FACTS devices that uses advanced compensation techniques is the D-STATCOM. D-STATCOM is adapted to the distribution systems of devices that contain

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advanced power electronic systems such as STATCOM and Static VAR Compensator (SVC) [4]. Both correction of the voltage amplitude and the elimination of harmonics are provided by this device. D-STATCOM devices also control the reactive power. Electric machines have windings and thus they cause inductive effects. This effects are eliminated by means of capacitors. D-STATCOM performs this task by switching the capacitors that it possesses at the time [5].

Many different methods are used to control D-STATCOM. The structure actually contains one voltage source inverter [6]. However, this inverter can be made in various types with different types of power electronics connections as well as multilevel inverter [7-9].

In this study, the indirect current control technique based on synchronous reference frame theory is used for control of D-STATCOM [10-12]. In this structure PI and fuzzy logic controller based PI controllers are used [11,13].

In the control system of D-STATCOM, the selection of modulation technique is also important. Different pulse width modulation techniques are used such as carrier based pulse width modulation [14], multilevel space vector modulation [15] and selected harmonic elimination pulse width modulation [16] in the literature.

In this study, D-STATCOM structure was investigated in wind energy systems and reactive power compensation was performed. D-STATCOM contains two level voltage source inverter. The structure was investigated using PI and MFLC-PI controller and results are compared. The D-STATCOM structure is shown when device is in operation and not in the system. The system is simulated in the MATLAB / Simulink environment.

2. TWO LEVEL INVERTER BASED D-STATCOM

This work focuses on the use of D-STATCOM from FACTS devices in wind energy, one of the renewable energy sources. In addition to adjusting the amplitude and frequency of the voltage obtained from wind turbine, reactive power control has been studied on the grid with reactive power compensation using different control technique. Figure 1 shows the main system block diagram.

As shown in Figure 1, D-STATCOM structure to be used for controlling the power to loads from the wind turbine consists of a two level inverter, a dc-link capacitor supplying the dc voltage requirement for inverter, a control circuit for switching and a coupling inductance for connection to grid.

2.1. Mathematical Model of D-STATCOM

In the D-STATCOM structure shown in Figure 1: C is the capacitance of the dc side; R, resistance; L, inductance; Usa, Usb, Usc represent the three-phase source voltage. The IGBT switching elements are considered ideal and the three-phase source voltage is balanced. High harmonics are also ignored.

Under the ABC coordinate axis conditions, the D-STATCOM mathematical model is shown in Equation (1).

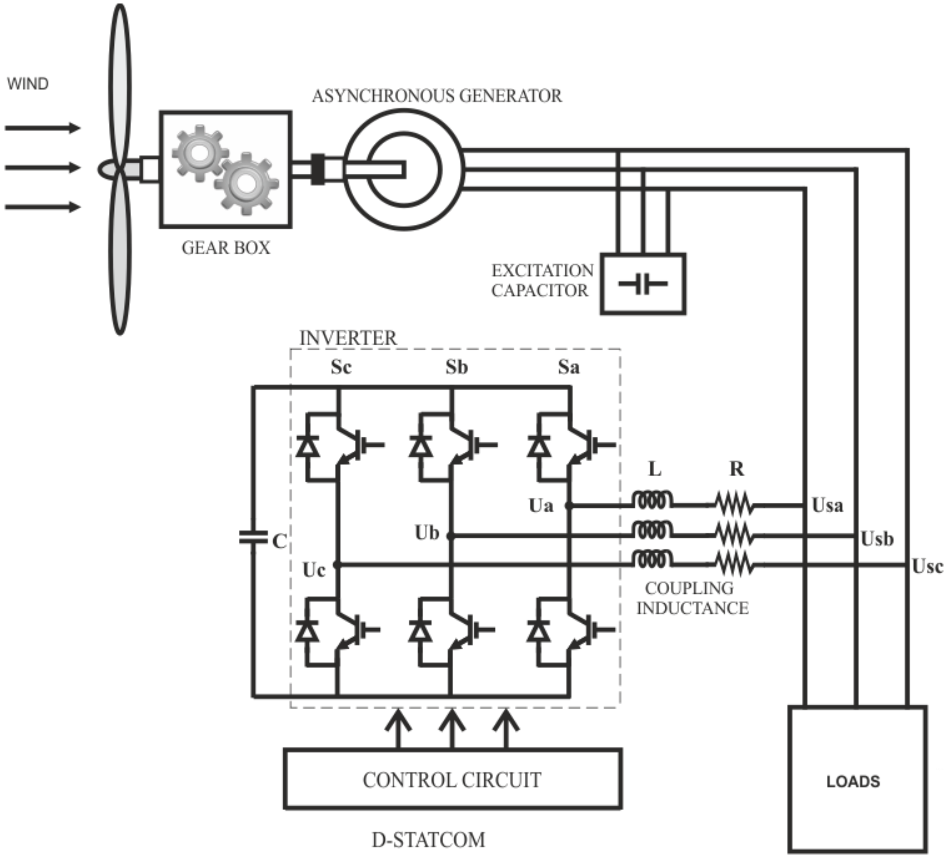

Figure 1. The main system block diagram.

$$\begin{cases} L\dfrac{di_a}{dt} = U_a - Ri_a - U_{sa} \\ L\dfrac{di_b}{dt} = U_b - Ri_b - U_{sb} \\ L\dfrac{di_c}{dt} = U_c - Ri_c - U_{sc} \\ C\dfrac{dU_{dc}}{dt} = s_a i_a + s_b i_b + s_c i_c \end{cases} \tag{1}$$

Sa, Sb, Sc are the switching functions and 1 is the value when the upper bridge is conductor and 0 when it is the lower conductor.

The equation on the ABC coordinate axis is very difficult equation for designing the control system because the variables on the ac side of the mathematical model are time dependent. For this reason, the ABC coordinate is transformed to the two-phase coordinate axis by the PARK transformation. The matrix of the ABC coordinate axis is transformed with the help of the PARK transformation matrix in equation (2) to the coordinate axes rotating simultaneously in the two phases.

$$T = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ -\sin\theta & -\sin(\theta - 2\pi/3) & -\sin(\theta + 2\pi/3) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \tag{2}$$

Conversion is done as idq0=T*iabc. Equation (3) is obtained using these two equations.

$$\begin{cases} L\frac{di_d}{dt} = s_d U_{dc} - Ri_d - U_{sd} + Lwi_q \\ L\frac{di_q}{dt} = s_q U_{dc} - Ri_q - U_{sq} - Lwi_d \\ C\frac{dU_{dc}}{dt} = \frac{3}{2}(s_d i_d + s_q i_q) \end{cases} \tag{3}$$

id and iq represent the current component of the two-phase rotating coordinate axis, sd and sq represent the switching functions. Thus the system equality is greatly simplified. According to the instantaneous reactive power theorem, the active power sent to the power system can be obtained P=Ud*id and the reactive power Q=Uq*iq. By controlling the id and iq components in this way, dynamic control of the active and reactive power sending system to the power grid can be achieved.

2.2 D-STATCOM Control Circuit

Figure 2 shows the block diagram of the indirect current control system with synchronous reference frame theory for D-STATCOM. In this control system, dc voltage is kept constant and the reference voltage that the inverter must produce are obtained according to the reference active and reactive power.

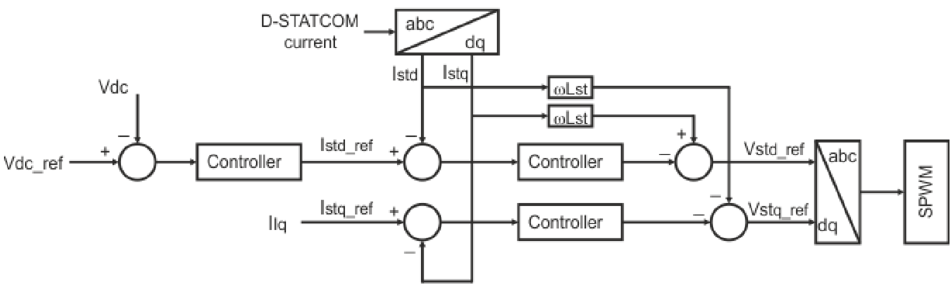

Figure 2. The block diagram of the indirect current control system.

Figure 3 shows the MFLC-PI controller architecture. The two coefficients Kp and Ki of the PI controller are set by the MFLC. These coefficients of the classical PI controller can not be set properly during non-linear parameter changes for nonlinear systems. In these cases it is necessary to set it automatically. The MFLC-PI controller adjusts the Kp and Ki parameters of the PI controller according to error and change in error.

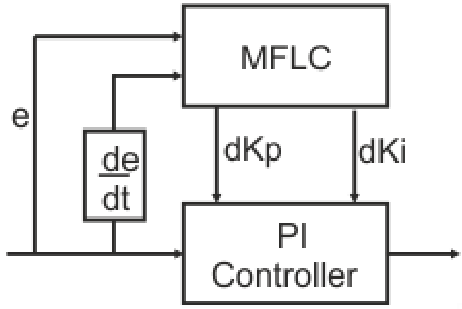

Figure 3. MFLC-PI controller architecture.

The MFLC structure consists of a fuzzifier, a rule base – fuzzy interface and a defuzzifier. As the first block, the fuzzifier converts crisp values into fuzzy values. These fuzzy values are sent to the rule base unit and the fuzzy interface. These processed fuzzy values are then sent to the defuzzifier unit. In this final unit, the crisp values are obtained.

All units in the internal structure of the MFLC-PI controller were created in the Matlab / Simulink interface. Triangular membership functions are used in the fuzzifier unit of the MFLC structure used for this system. In the rule base unit, these values are processed with 25 rules, 5x5 pieces. Finally, in the defuzzifier unit, the center of area method is used. Detailed information is given in article [17].

3. RESULTS AND DISCUSSION

Figure 4 shows the D-STATCOM response during load changes. The variation of the reactive component of the D-STATCOM current (istq) versus the change of the reactive component of the load current (ilq) is seen in this figure.

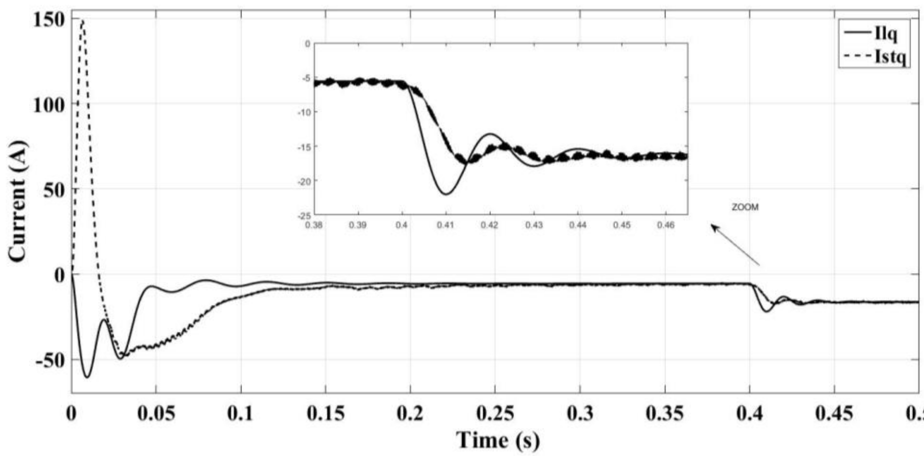

Figure 4. ilq – istq changes during load changes.

Figure 5 shows active and reactive power changes at the load side. When 4kW asynchronous motor load and 1kW R load are connected to the system, 3kW R load is applied at 0,3 seconds, 1kW R load and 5kVAr inductive load are applied at 0,4 second.

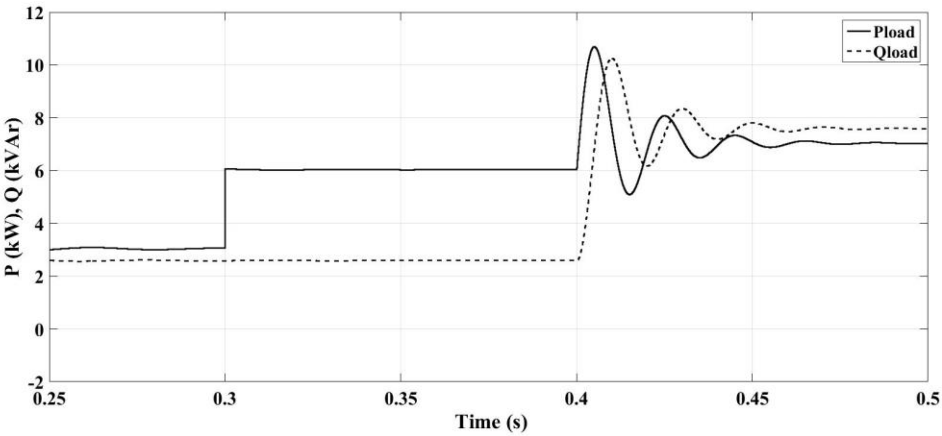

Figure 5. Load P-Q changes

Figure 6 shows active and reactive power changes at the point of common coupling (PCC) where D-STATCOM is connected to the system during load changes.

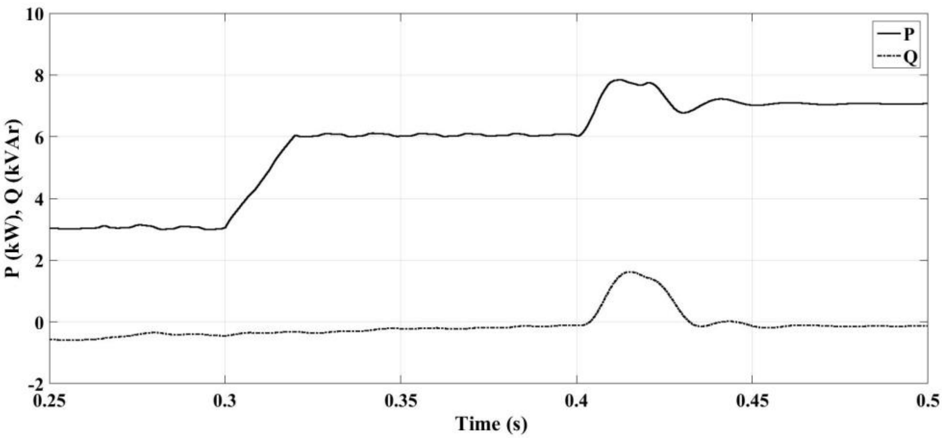

Figure 6. P-Q changes at the PCC

Figure 7 shows the voltage and current changes at the load side for one phase. There is phase difference between voltage and current in this Figure because of load reactive components. In this figure, current multiplied by 10.

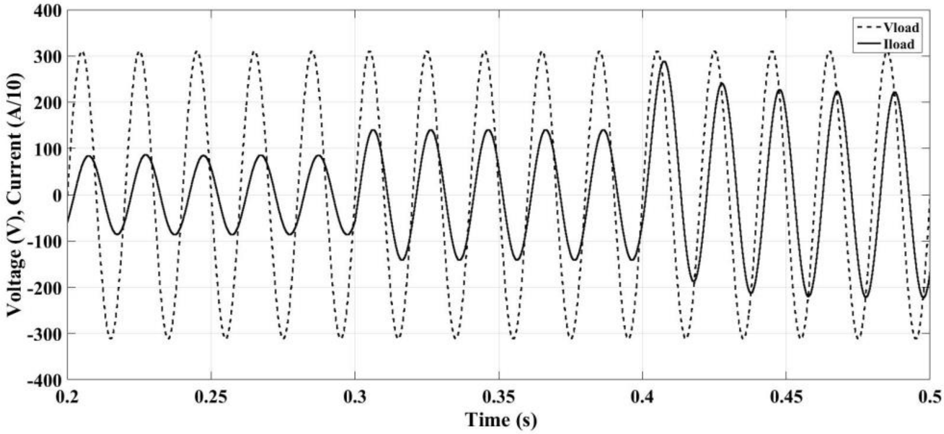

Figure 7. Load current and voltage changes.

Figure 8 shows the voltage and current changes at the PCC. It seen that there is no phase difference between voltage and current in this way which should be examined in terms of power factor.

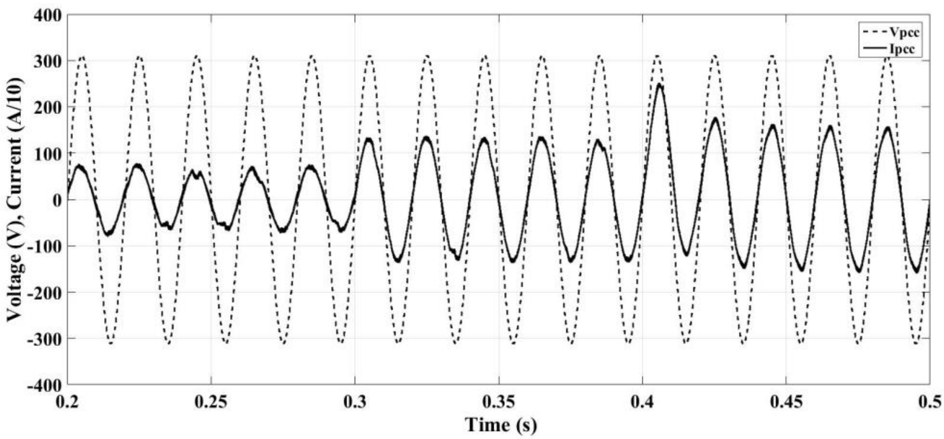

Figure 8. Current and voltage changes at the PCC .

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