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Optimization and Validation of Model Predictive Controller (MPC) Approach for Wind Turbine Energy System in Domestic Loads

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HIGHLIGHTS

- A novel MPC controller for Wind turbine system (WTS) is proposed to control the turbine actuation system using intelligent fuzzy logic.
- The controller proposed with the small actuator that defines with WTS will tackle losses associated during operation and rotation of WTS.
- The simulation outcomes suggest the proposed controller and further reduce ripples with various operating ranges in domestic loads holds better results compare to conventional one.

Abstract: In this paper, a novel MPC controller for Wind turbine system (WTS) is proposed to control the turbine actuation system using intelligent fuzzy logic. The main limitation of wind turbine system is power regulation and frequent transient operation which defines the WTS as unstable among other renewable energy sources. The proposed controller defines the WTS to operate in nominal conditions with high improved performance during capture of wind energy system which maintains the load safe and operate-able to all condition. The controller proposed with the small actuator that defines with WTS will tackle losses associated during operation and rotation of WTS. The complete WTS with actuator model and fuzzy control based MPC controller designed in MATLAB/SIMULINK environment. The simulation outcomes suggest that a better transient response and high energy delivery obtained during the usage of proposed controller and further reduces ripples, further the proposed work tested with various operating ranges in domestic loads holds better results compare to conventional one.

Keywords: MPC; Fuzzy; controller; WTS; actuator; THD; MATLAB.

INTRODUCTION

Wind turbine system actuation systems are complex, non-linear patterns subject to uncertainties with models to improve the performance of tracking applications to improve actuation system performance discussed [1]. Much of the existing wind turbine system relies on wind turbine operating regions. The energy extraction rates proposed [2] are low and the structural loads are within allowable values. The automatic actuation control system used in fins and gliders to maintain constant torque performance for various dynamic loads and thermal object loads [3-4]. The drive system for a BLDC generator on current control techniques using PWM signals [5-6]. Further the development of the position and speed control for various applications between the controllers, conventional PID is the most popular controller in practice has poor dynamic behavior for non-linear loads in real-time applications. The deficiency is the use of MPC limited to stabilization problems, while general tracking problems have not been considered [7-8]. The MPC control sequence with a local auxiliary tracking law to drive the system to an intermediate safe reference specifically provided by the MPC to be reached in an admissible analyzed manner [9]. In this article, MPC fuzzy control algorithm model integrating fuzzy PID controller and brushless DC generator with wind power system as shown in Figure 1. The control algorithm performs fast operation with fuzzy PID controller for nonlinear systems and overcomes its oscillatory response by changing the gains of the fuzzy PID controller.

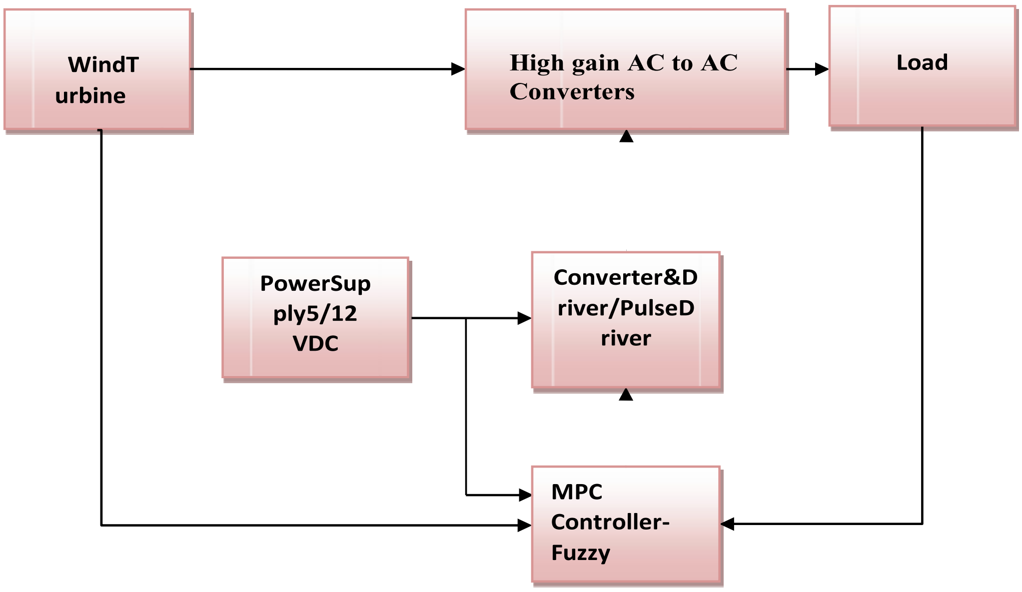

Figure 1. Wind Energy Conversion system

To verify the proposed system, the complete configuration was simulated in the MATLAB-SIMULINK environment. In this paper, model of MPC-fuzzy control algorithm integrating a fuzzy-PID controller and a Brushless DC generator with wind energy system. The control algorithm performs fast operation with fuzzy-PID controller for nonlinear systems and overcome its oscillatory response by switching gains of the fuzzy-PID controller. To verify the proposed system the complete setup was simulated in MATLAB-SIMULINK environment.

MATERIAL AND METHODS

The design of a predictive controller system is based on input of WTS system and BLDC generator further fed to calculate the parameters on described output with present and past control signal as the adjustable variables represented in Figure.2. The drive control parameters assumed to have the current time is ki, k_d and kp values with the length of the optimization is considered to be Np with defined numbers of samples as considered to be the single output, input and control signal.

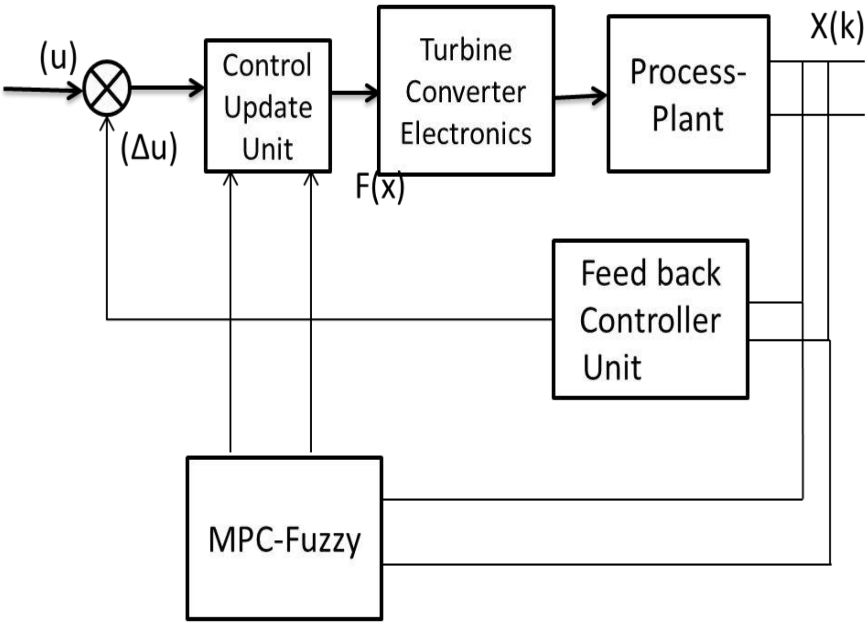

Figure 2. Block diagram of MPC controller design

In proposed fuzzy control MPC proposed with multiple loops the first closed loop is a current controller performs in limiting the maximum current to protect the generator and second closed loop is speed controller to maintain the fin at desired speed limit.

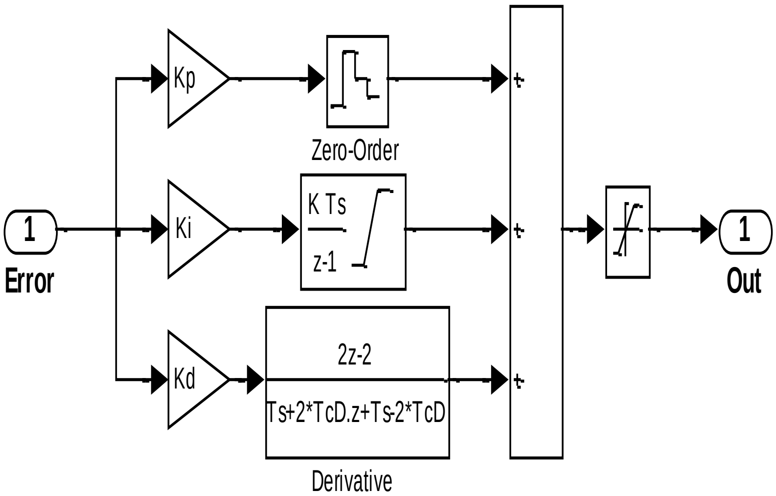

Figure 3. Fuzzy gains controller

The model of fuzzy controller gains with feedback as shown in Figure 3 the gain values Kp, Ki and Kd are differed as per the position and current magnitude working ranges. From the control law, the mathematical formulation of discrete MP-controller is formed as per equation. The MPC control parameters are tuned based auto tuning set by fuzzy logic and here 7*7 logic systems is used to drive system with universal constants between 0 and 1.

RESULTS AND DISCUSSION

The simulation of the integrated controller and wind turbine system carried out in MATLAB/SIMULINK environment as shown in Figure 4. The wind energy system is designed and results obtained through operating under various operating conditions were benchmarked with the conventional controller and proposed MPC method. Brush Less DC (BLDC) generator model in wind turbine system to harness maximum energy from wind and transfer to the turbine and through converter electronics model that feds to the domestic load.

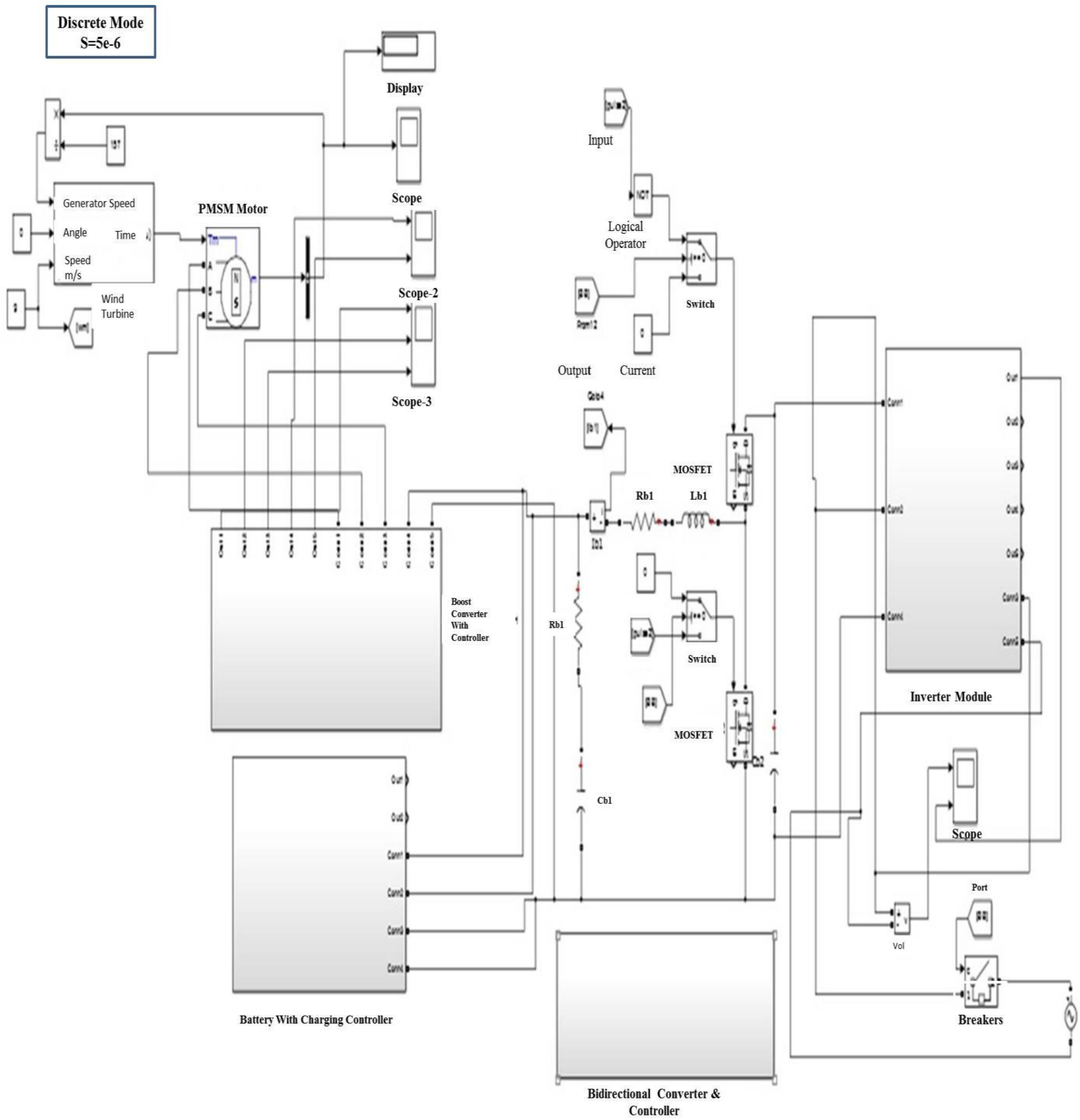

Figure 4. Proposed MATLAB model

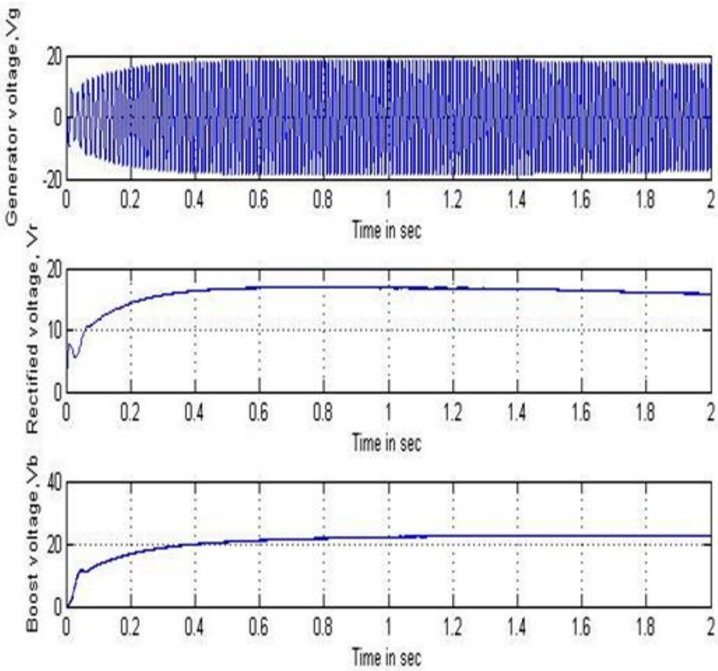

Figure 5. Generator and boost converter output waveform

The obtained results of BLDC generator simulation as shown in Figure 5 further the results of generated voltage through wind turbine, with turbine electronics output of DC voltage fed to converter to boost voltage as listed. Rectifier unit accountable to convert AC to DC using converter pulse operated using proposed controller. As results outputs are constant with increase in the load and further a step-up converter incorporated to obtain maximum power from source.

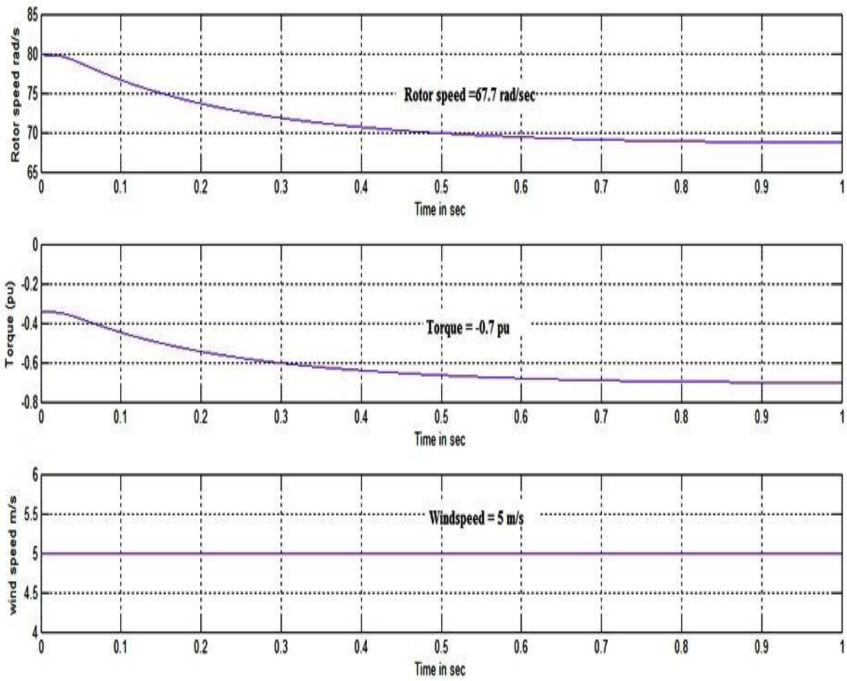

Figure 6. Turbine converter output waveforms

The proposed WTS supports to concept of bidirectional flow of power during unstable conditions to drive wind blades. Figure 6 is output waveform of converter which offered to operate in boost output signal waveforms. As the DC input voltage 24V is boost to 44v by controller pulses based PWM pulsed fed by MPC controller using fuzzy as set by operator. As a result the simulated waveforms show better performance than with the conventional controller and the MP- controller fuzzy mode controller and proved from Figure 7 and

8 shows wind output parameters with load voltage and load current respectively observed when the MP-controller is implemented.

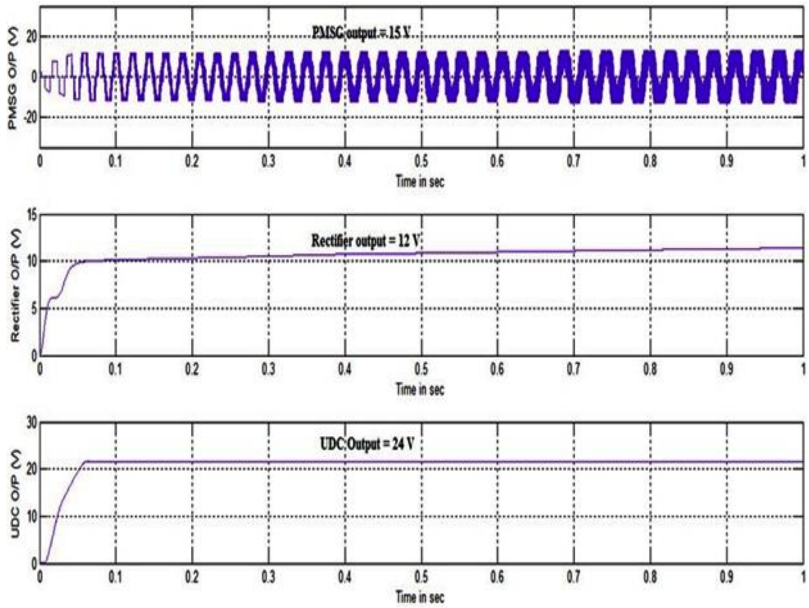

Figure 7. Wind profile parameters with MP Controller

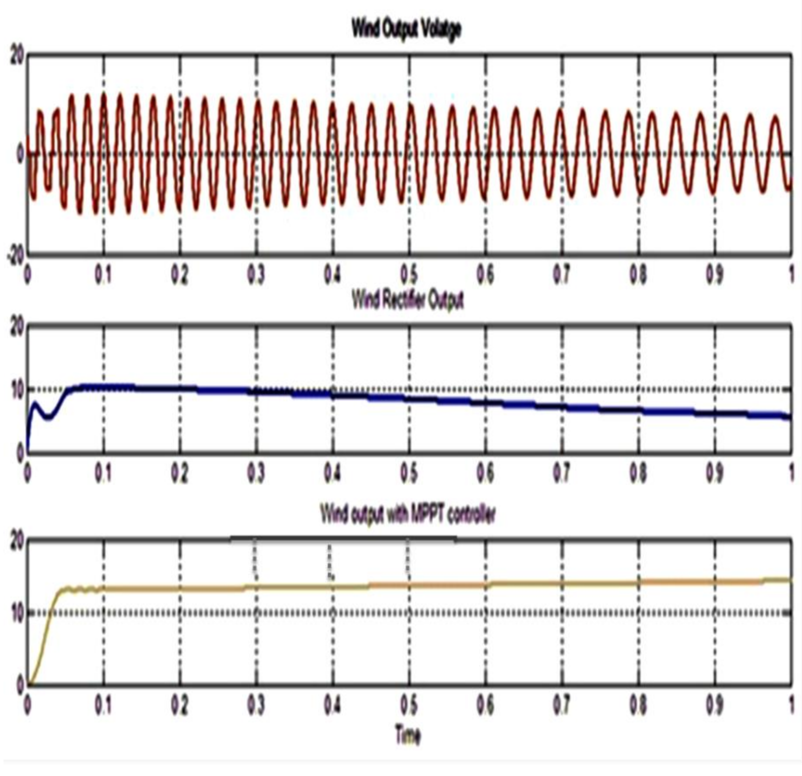

Figure 8. Wind output voltage profile

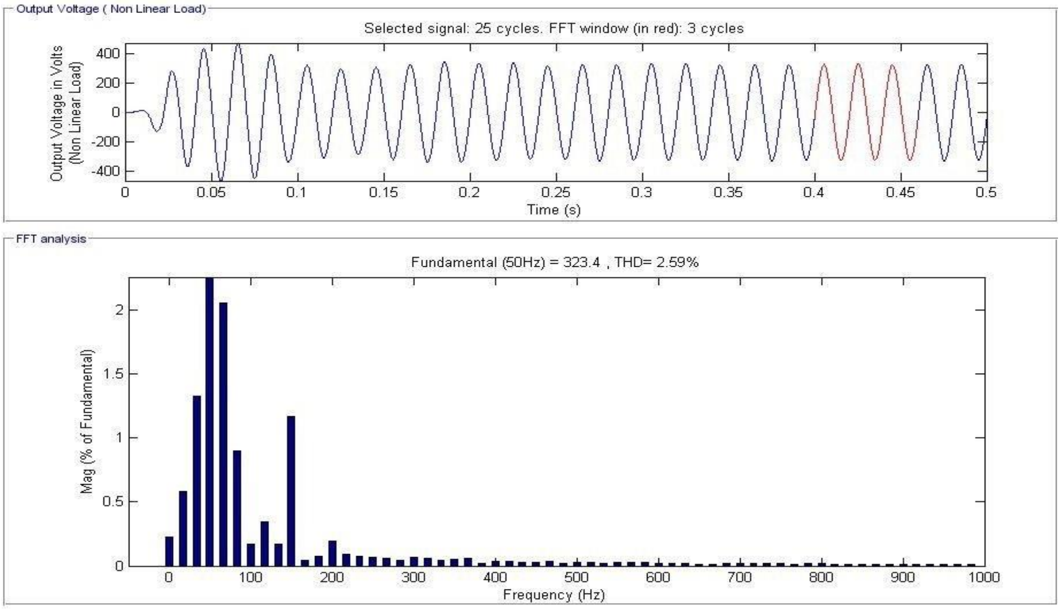

Figure 9. THD for output voltage (Nonlinear load)

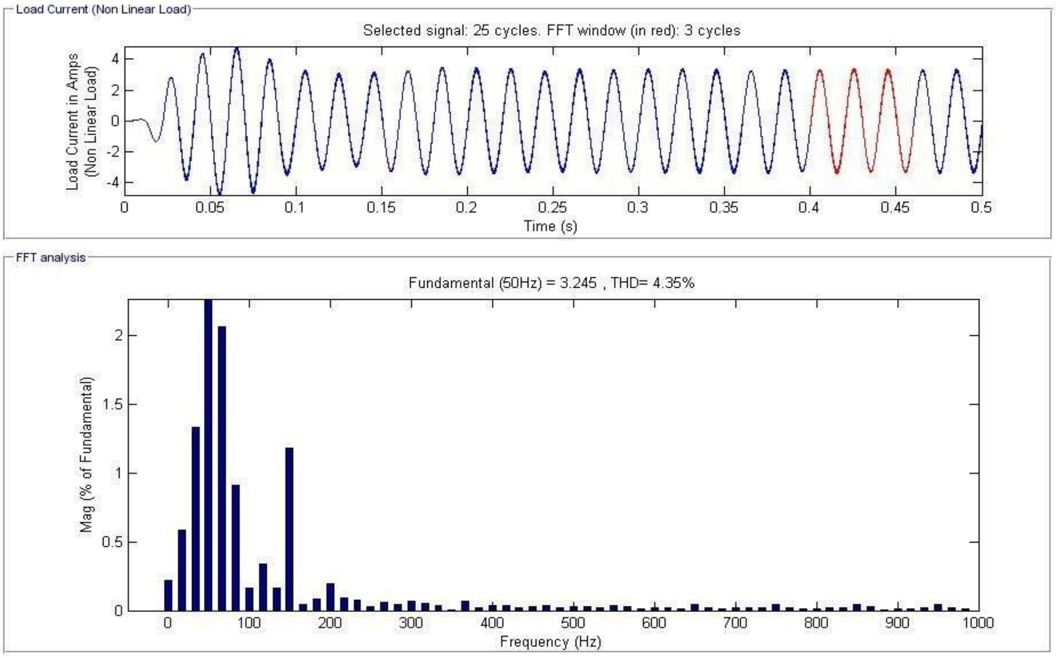

Figure 10. Total Harmonic Distortion of the load current (Nonlinear load)

Table 1. Comparison of THD value of output voltage and load current generated with conventional and proposed controller.

Sl.No	Control scheme	Type of load (W)	$V_{O(rms)}$ Volts	Load current (I_{load}) amps	% THD for V_O	%THD for I_{load}
1	Conventional fuzzy controller	lineal	227	3.3	4.85	9.59
		no lineal	226	3.1	4.83	10.21
2	MP Controller with Fuzzy	lineal	229	3.4	3.95	3.95
		no lineal	227	3.3	2.59	4.35

The obtained simulated results of WTS and input fed as to inverter compared and listed with conventional controllers and proposed controller is analyzed with their respective THD values of voltage and current signals as shown in Figure 9 and Figure 10. The total harmonic distortion of output voltage and load current of linear and nonlinear load is tabulated in Table 1.On observing the table it is proved that the voltage and current quality with respect to linear as well as nonlinear load is inacceptable range, which has been proven by the THD values of the voltage and current signals generated by using model predictive controller in single phase inverter of solar power generated system.

CONCLUSION

In this paper, the fuzzy based-MPC controller based WTS system developed with for the several stages of power conversion and control with wind sources. Compared with the conventional WTS system electronics the proposed work maintains balance between load and source side, fuzzy logic defines the rules and strikes a balance between the power reference tracking and desired source based output voltages in wind turbine loads. Model Predictive controller designed with fuzzy controller intelligent techniques introduces effective optimization of fuzzy parameters in various testing and training models for fuzzy controller. The proposed technique is compared with fuzzy controller for output of turbine converter factors such like load voltage & current and THD values in output side and load side. The proposed MP tuned fuzzy controller greater in minimization of THD values from 10.21 to 4.35 for non-linear loads and for linear load from 9.59 to 3.95. The proposed MO controller with fuzzy in design of turbine converter stabilizes the wind energy system with non-uniform of wind fluctuations. The robustness of proposed fuzzy-MP controller reduces the errors and maintains stable of system parameters in WTS system for real-time control of modern wind farms.

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