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Design of FOPID controller for 7Level multi-inverter integrated with closed loop boost converter system

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ABSTRACT
In this article, various controllers were explored: PI and FOPID Integrated with Boost Converter to strengthen 7-level multi-inverter output. Each system shall be calculated with its total output power and THD. This analysis seeks to broaden the understanding over the efficiency of seven levels Cascaded H-Bridge multi-level inverter topology with PI and FOPID closed loop Boost Converter using PWM technique for fixed DC. The output is the amount of the voltage each bridge produces. The proposed topology includes FOPID closed loop Boost Converter on the input side, which enlarges the basic outcome voltage and reduces the total harmonic distortion. The angles can be structured in such a way attempts to minimize harmonic distortion. The MLI topology simulink model has been developed and simulation studies have been carried out successfully. The simulation is carried out and the results of MATLAB are presented. The results comparison shows that for the MLI with FOPID controller is very promising. The analysis of designed controller is verified at disturbed operating conditions via.

Keywords - Multi level Inverter (MLI), Fractional order PID (FOPID), Sinusoidal Pulse Width Modulation (SPWM), Cascaded H-Bridge Multilevel (CHBML).

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I. INTRODUCTION

Power Electronics is the technique for accurate, tidy, nimble and flexible, nimble electrical energy converting from one form to another for convenient use. It has become an important center of power and energy control in modern technology. This technique is used to convert energy, control and condition electric power from the source onto the required output. [1]. In different earlier applications the demand for electricity is gradually increasing. In the preceding years, electricity production depended primarily on non-renewable fuels like fossil fuels, coal , natural gas, oil imposed by the environment as well as on earth's temperature[2]. For this reason, the government is now being promoted to use a clean energy source, such as solar, ocean and wind, to generate electricity in response to the demand it desires [3]. All these implementations are achievable because of the skill of the MLI to supply smarter voltage. A more sinusoidal shaped waveform and better efficiency due to the relatively low operation of the switching frequency and reduced dv/dt stress [3]. Most suggested configurations are based on complementary switch strategies that involve the use of a dead-time switch to prevent the conversion shoot [4]. Multi-stage inverter (MLI) has significant benefit, like lower harmonic output content; improved voltage sharing, normal and transient condition; volume reduction is possible through the removal of the coupling transformer, operates with a lower frequency compared with normal pulse width modulators, thus minimizing switching losses[5].

This article presents an exquisite response to the hybrid fractional order PID controller optimized by means of a traditional proportional integrated derivative controller (PID). The first is Ziegler-Nichols and the second is Astrom-Hagglund. Here both tuning methods are used for the evaluation of PID-controller's parameters. The parameters in use by Ziegler-Nicholes and the derivative constant are the proportional and integral constant of the FO-PID controller [6]. The PI and the FOPID, or boost converter unit, comprise a novel MLI topology in this paper. Here, FOPID controls have been designed to decrease harmonic distortion and enhance overall system efficiency. This paper is organized accordingly. Section II discusses with the needed concepts the proposed MLI structure. Section III compares total harmonic distortion while Section IV discusses proposing controller. Section 5 gives simulation results and finally gives the findings.

II. BASIC OF 7LEVEL INVERTER

The inverter topology of 7 levels resembles the topology of 5 levels, only the auxiliary system has been added to it by a further circuit. Generally speaking, seven levels consists of an inverter full-bridge, two bidirectional (auxiliary) switches and three capacitors as a voltage source outlined in figure 1. High dc bus voltages are required to ensure that energy flows from source to the load . The LCL filter filters the current into the utility grid that is to be injected. If the IGBTs switching signal in topology is handled correctly, seven output voltage levels can be reached. The interrupting combinations generated in Table II of the seven output voltage levels [7]

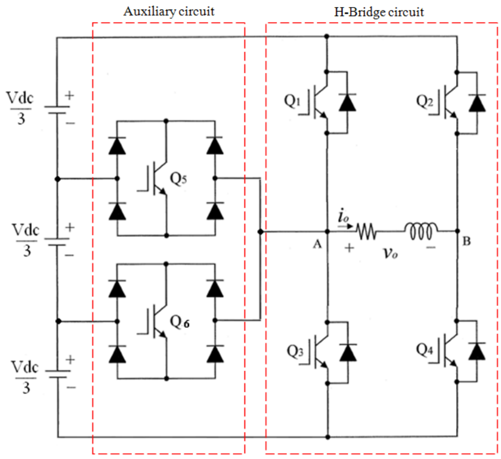

Figure1. Structure of 7-level multilevel inverter

Table 1. The legs ON/OFF for 7level inverter

Output Voltage	S1	S2	S3	S4	S5	S6
+Vdc	One	Zero	Zero	One	Zero	Zero
+2Vdc/3	Zero	Zero	Zero	One	One	Zero
+Vdc/3	Zero	Zero	Zero	One	Zero	One
0	Zero	Zero	One	One	Zero	Zero
0*	One	One	Zero	Zero	Zero	Zero
-Vdc/3	Zero	One	Zero	Zero	One	Zero
-2Vdc/3	Zero	One	Zero	Zero	Zero	One
-Vdc	Zero	One	One	Zero	Zero	Zero

Key: One=Switch on , Zero=Switch off [7]

III. TOTAL HARMONIC DISTORTION

THD is defined as the share of the powers of all harmonic components with the power of the fundamental frequency. The following expression can be presented (1)

$$THD = \sqrt{I_1^2 + I_2^{\,2}} + ...I_\infty^{\,2} \qquad (1)$$

For the current waveform, formula above is the Linearness of systems and the power qualities of electric systems are portrayed by THD. In accordance with the IEEE THD standard, the total harmonic distortion of current is less than 5% of the rated inverter current. Section V shows THD for the simulated model.

IV. FOPID CONTROLLER

A fractional order should offer the following advantages compared to an integer order controller.
(a) The fractional order controller will be less tolerant than a classic PID controller when the controlled system parameter changes.
a) FOC has 2 additional tune variables. The performance ratio of the fractional order system is provided with additional liberty.

Industrial plants require a wide range of standards to be met. Integer order controllers are used for control purposes mainly for industrial applications.
The FOPID control unit is now being optimized to enhance system control performance in industrial applications. This controller's transfer function is the form below(2)

$$G_c(s) = K_p + \frac{K_i}{s^{\lambda}} + K_d s^{\mu} \qquad (2)$$

For not only the need for Kp, Ki, kd design controllers, but also design orders for integral and derivatives, the FOPID controller offers extra liberty.

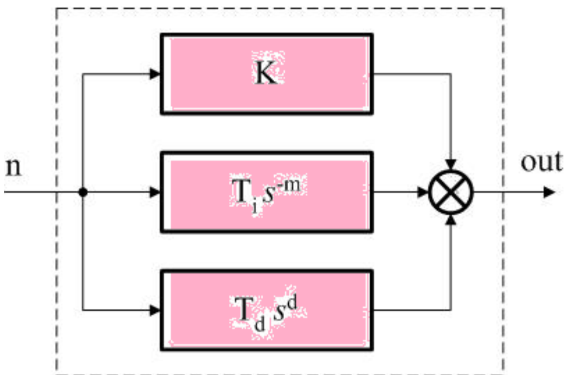

Fig.1a. Block diagram of FOPID controller

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V. SIMULATION RESULTS

a) Open loop 7level inverter with boost converter

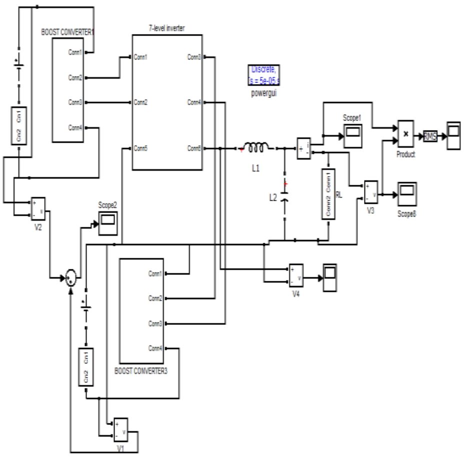

Fig.2. Circuit diagram of 7-level inverter source disturbance.

This section discusses simulation results for 7-level inverters compared to PI and FOPID for a designed controller. MLI system simulation is performed with the software MATLAB. MLI is used to feed a R load. In order to increase the inverter output to the required level, MLI associated with the boost converter. The simulink diagram of boost converter with 7-level inverter source disturbance is shown in Figure 2. The currents and voltages are measured using scope. Figure.3 displays the input voltage for the converter to boost and its value is around 72V and step disturbance at 1sec. Figure 4 illustrates the switching pulse of the boost converter. Fig.5 shown over the boost converter voltage and boosted to 230V. The 7-level inverter with open-loop boost converter connected to the R-load at the end and load voltage is about 230V with little perturbation. It was displayed in fig.6The load R current is approximately 3A, as shown in fig.7. Due to sudden system changes and the absence of closed controls, at 1sec the waveform has disturbed. This effect can increase THD more than the limit specified. The fig.8 shows output power of the open loop inverter.

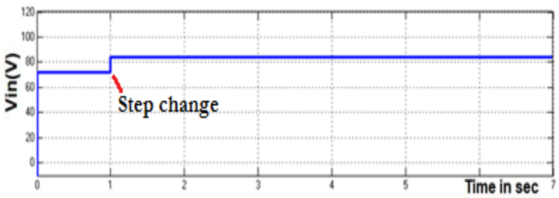

Fig.3 Input voltage with disturbance

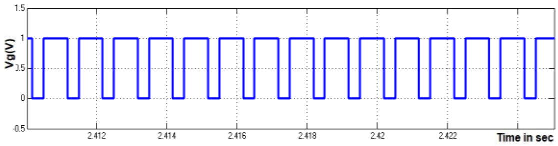

Fig.4 Switching pulse of boost converter

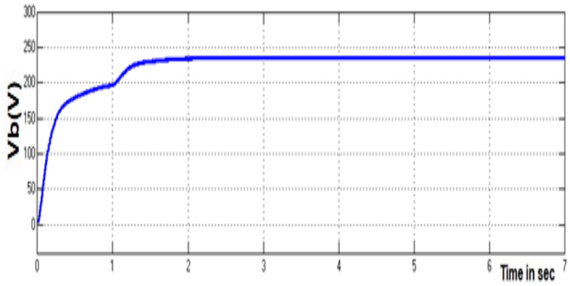

Fig.5.Voltage across boost converter

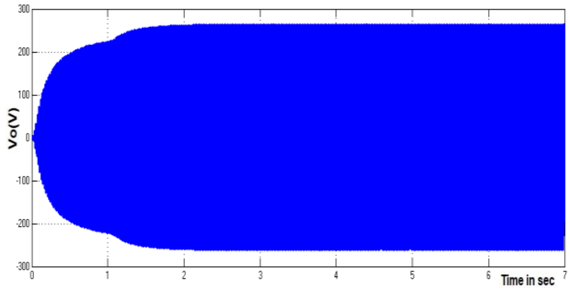

Fig.6. Voltage across R-load

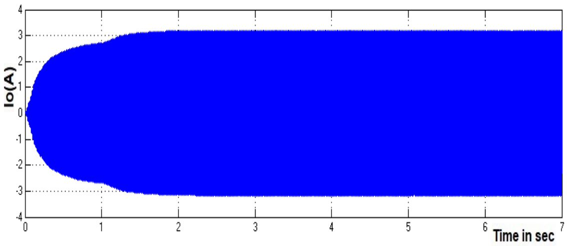

Fig.7. Current across 7 level inverter

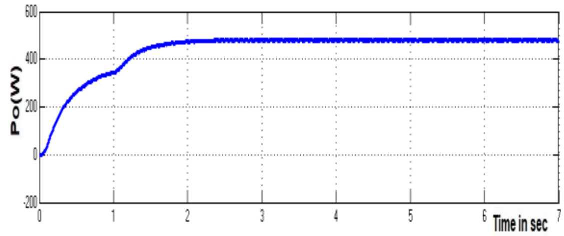

Fig.8 Output power of inverter

b) Boost converter with 7-level inverter closed loop PI controller

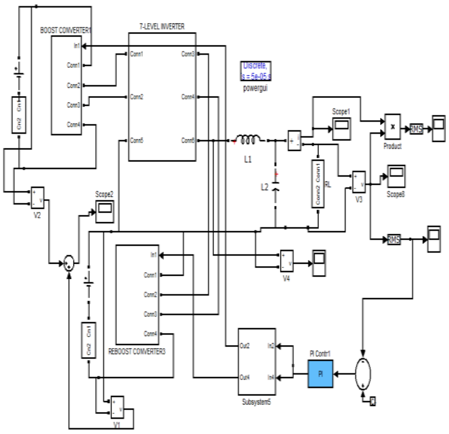

Fig.9 Boost converter with 7-level inverter closed loop PI controller

Fig.9 Shown Boost converter circuit diagram with closed PI controller inverter of 7 levels. This subparagraph provides the simulated PI controller-7 level inverter results. Analyzing THD line voltages is the justification behind the design of this high level inverter. The designed PIC has been connected to the DC boost converter response based on error signals. The PIC designs are made by the Zeigler-Nichols tuning method with a proportional gain (Kp) and integral time (Ti). In the context of Tables 2 suggested Time Domain Parameters of both PI and FOPID.

Clear waveform structure and THD of the system suggested were shown from fig 10 to 10f. Small step changes were made to indicate the efficiency of the controller in Fig . 10 at 1 second and controlled reduces the waveform oscillation, and reduces voltage THD and current THD by 4.57 and 4.55% respectively. The time domain parameter PI are Tr = 1.35, TS=6.00 , Tp=3.42 and Ess =3.3.

Table.2. Comparison of Time Domain Parameters

Controller	Tr	Ts	Tp	Ess
PI	1.35	6.00	3.42	3.3
FOPID	1.24	4.00	2.34	2.1

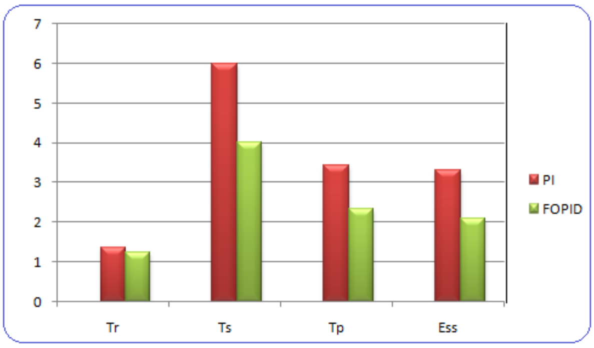

Fig.9a. Time domain of PI and FOPID

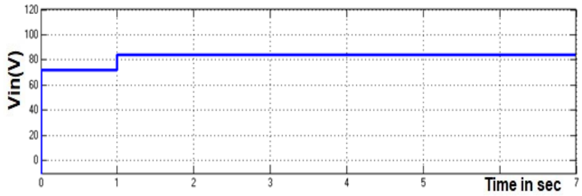

Fig.10.Input voltage

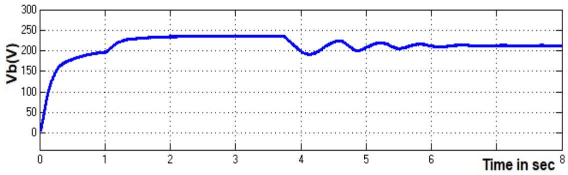

Fig.10a Voltage across boost converter

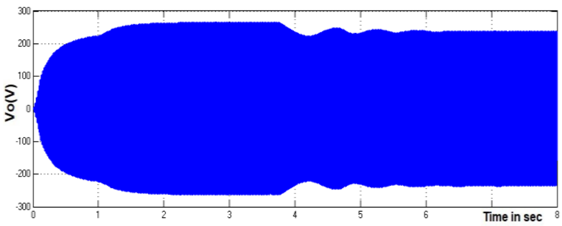

Fig.10b. Voltage across R-load

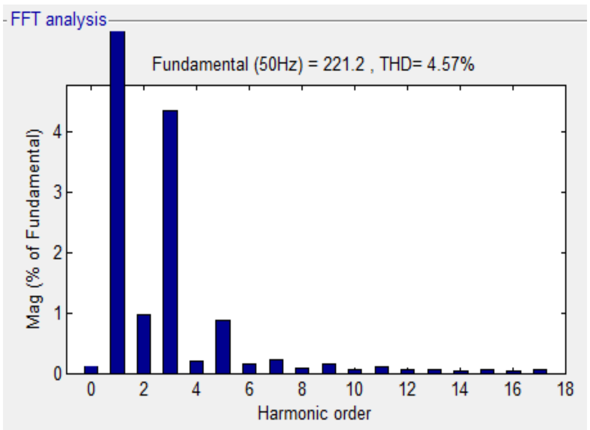

Fig.10c. Voltage THD

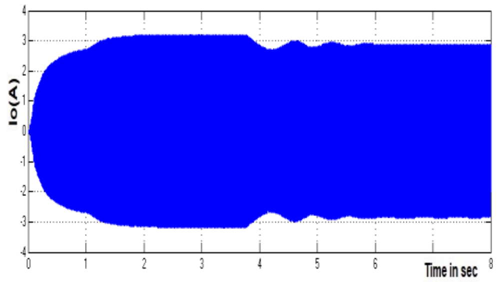

Fig.10d Current through R-load

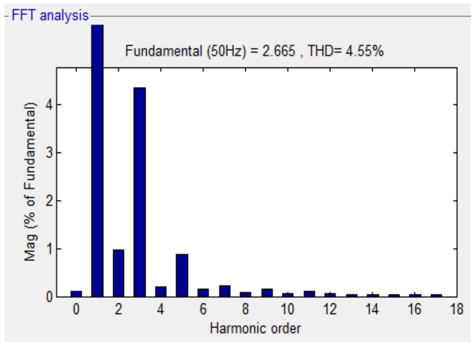

Fig.10e.Current THD

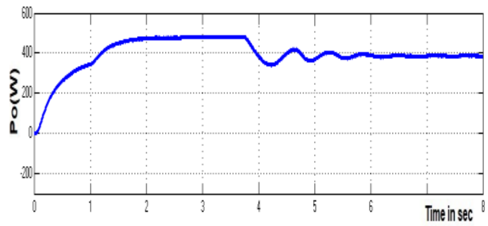

Fig.10f. Output power

C. Boost converter with 7-level inverter closed loop FOPID controller

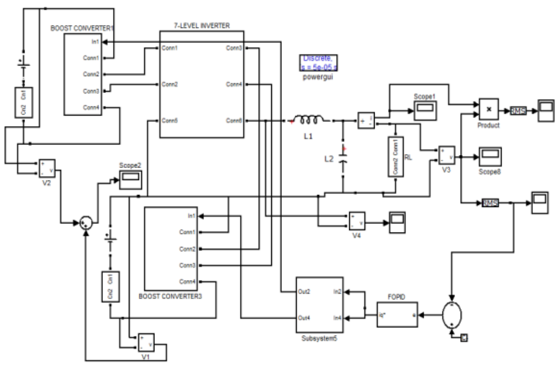

Fig.11. Circuit diagram of boost converter with 7-level inverter closed loop FOPID controller

In fig.11 shows complete simulation model of FOPID based controller. The THD reduction with support of FOPID was shown observed. The proposed system's efficiency is much greater than conventional PI controller.

The FOPID have Tr=1.24, Ts=4,Tp=2.34, Ess=2.1. The steady state error of proposed system shows its superiority and reduces Ess to 1.2 compare to PI.

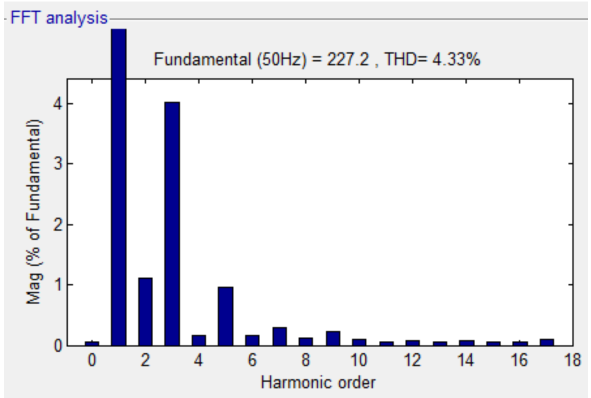

Fig.11a.Voltage THD

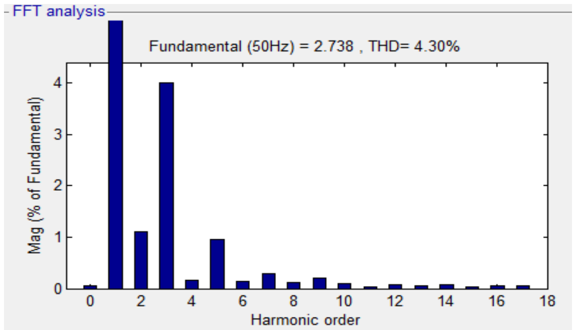

Fig.11b Current THD

Table.3. Comparison of THD for PI and FOPID

Controller	Voltage THD(%)	Current THD(%)
PI	4.57	4.55
FOPID	4.33	4.30

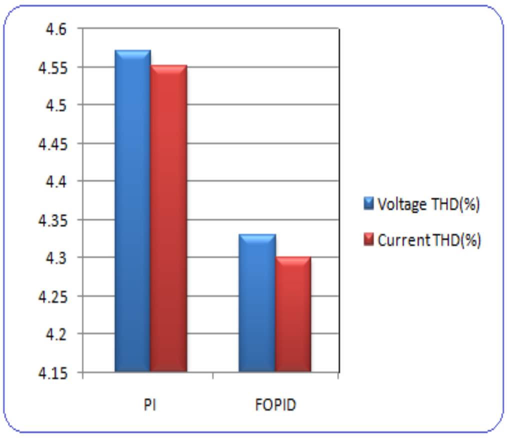

Fig.11c voltage THD andCurrent THD in Bar chart

VI. CONCLUSION

In this report, the seven-level FOPID multilevel inverter provided more convenient THD, good performance and efficiency than the 7-Level PI multilevel inverter based on simulations and results. All the waveforms required were positioned in the correct way to understand controllers important. The integration of 7level MLI with the FOPID controller is also better for achieving free harmonic output. The voltage THD and current THD of the proposed system have reduced to less than 4.5%. Since steady state error of FOPID is lesser than PI controller system get less oscillations. FOPID is highly promising in the place of control techniques.

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