THE OUTPUT VOLTAGE QUALITY OF THREE PHASE MULTILEVEL INVERTERS CONSIDERING COGENERATION SYSTEMS

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ABSRACT

In This paper solar, wind and fuel cells based stand alone cogeneration systems are presented for remote area utilities applications. The solar, wind and fuel cells based co generation system output voltages are not constant or stable in always. The generated output voltages are directly connected to the loads or utilities without battery bank or energy storage devices. A PI-control method was proposed in this paper such that the output voltage of converter circuit is constant even though input voltages are fluctuation conditions. A three phase three level, five level inverter with 3kw,5kw static load and dynamic load was examined to validate for proposed work in MATLAB environment.

Keywords: Closed Loop Feedback Control; Cogeneration Systems; Voltage Fluctuations; PI-Control; SPWM.

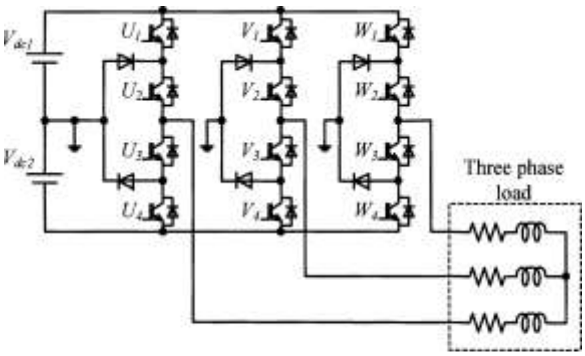
I INTRODUCTION

As one solution for the problem of environmental worsening and energy shortage, co-generation system using natural energy and fuel cell widely increasing. The electric power generated from these systems is converted to AC voltage by the inverter, after it is stored as DC electric power in the battery. In case of the system of power generation using natural energy and fuel cell, comparatively large fluctuation is generated at the DC voltage [4]. As this counter measure, improvement of voltage utilization factor by the superposition of the third harmonic wave was applied to absorb this voltage fluctuations [8]. The feed back control of output voltage was applied for the stabilization of output voltage. In addition, the output voltage in the ideal modulation without the distortion was obtained by controlling superposition ratio of third harmonic wave with the fluctuation of DC voltage. As a circuit converted into AC power from DC power, the multilevel inverter circuit was applied considering the reduction in switching component and capacity an expansion. The multilevel inverter is possible to reduce lower harmonic wave and switching component by outputting many voltage levels [9]. It is possible to output stabilizing AC voltage by the absorption of the fluctuation of DC voltage. And it will be possible to reduce the capacity of the DC capacitor [4][5].

In an effort to improve efficiency and voltage quality, a simple control method for improving the voltage utilization factor of multilevel inverter[9]. In this paper a control method which introduced the control of superposition ratio of third harmonic wave into output voltage feedback control and improvement on voltage utilization factor is proposed. It is applied to the multilevel inverter, and the operation principle and features are explained. Block diagram of co-generation systems is an explained in Fig2. Which including Solar, Wind and fuel cells system .The fluctuated inputs are converted to stable output by using Multilevel inverter. By simulation the validity of proposed control has been confirmed.

II. CIRCUIT CONFIGURATION

The circuit configuration is shown in Fig. 1.This circuit is an ordinary three-phase 5level inverter composed of 12 IGBTs, 6 diodes, and 2 DC sources. With *E* denoting the voltage of one DC source, the output provides five levels of line voltage, namely ±2*E*, ±*E*, 0. In addition, pulse width modulation is applied in order to reduce harmonic components. With more voltage levels, the content of switching components is reduced, and the generation of harmful harmonics is suppressed [8].



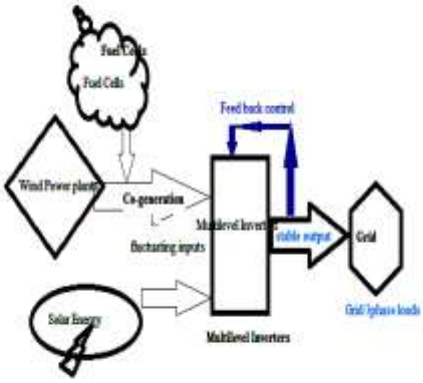


Fig. 1 Circuit Configuration. **Fig.2 Block Diagram of Co-Generation System Integration**

III. CONTROL METHOD

In the proposed control method, the basic PWM control block used conventionally for multilevel inverters is supplemented by output voltage feedback and improvement of the voltage utilization factor.

Assuming the use of a general-purpose digital control system, we aimed at the minimizing individual phase control in order to simplify control processing. A block diagram of the proposed control method is shown in Fig. 2, and detailed explanations are given below.

3.1 Output voltage tracking control

Two phase output line voltages V_{RY} and V_{BR} are taken into the Simulation the following can be obtained from the fundamental equations for a three-phase three-wire system, and from the relationship between the line voltages and phase voltages:

$V_{RY}+V_{YB}+V_{BR}=0$

$V_{RY}=V_{BN}-V_{YN}$

$V_{YB}=V_{YN}-V_{BN}$

$V_{BR}=V_{BN}-V_{RN}$ ……………………..(1)

Therefore,

$V_{BN}=1/3(V_{RY}-V_{BR})$

$V_{YN} = 1/3(V_{YB} - V_{RY})$

$V_{BN} = 1/3\ (V_{BR} - V_{YB})$……………..(2)

Three phase voltages V_{RN},V_{YN} and V_{BN} are converted into two-phase AC voltages $V\alpha$ and $V\beta$ by using the following:

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = \frac{\sqrt{3}}{2} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{RN} \\ V_{YN} \\ V_{BN} \end{bmatrix}$$
…………………..(3)

Now the magnitude V_{out} of the resultant output vector is calculated as follows:

$$V_{out} = \sqrt{|\dot{V}_\alpha|^2 + |\dot{V}_\beta|^2} \quad \text{………… (4)}$$

The magnitude Vout corresponds to the effective value of the output line voltage, which is a DC value in the case of a three-phase balanced voltage without fluctuation. Therefore, tracking control of the output voltage can be implemented by maintaining this value at a stable level [8].

The difference between the output voltage references V*out and the resultant vector magnitude Vout is given to the proportional integrator, and the DC voltage compensation on V_{pi} is calculated. A coefficient related to the superposition ratio α is applied to this value, and then a sinusoidal reference is obtained by multiplying by a three-phase sine Wave with amplitude of one[7][8].

The advantage of this system is obtaining the fixed control characteristic, when the AC voltage of any frequency is output, because the signal input to the proportional integrator is the instant DC voltage which does not depend on the frequency of the output

Voltage. That is, the method can be applied to variable speed drive of electric motors and to other cases when a variable-frequency source is required.

IV. PWM CONTROL

As shown in Fig 2, after output voltage tracking and Improvement of the voltage utilization factor, the three phase signals V^*_R V^*_Y, and V^*_B are compared to two triangular carrier waves with positive and negative offsets. The PWM signals thus generated are passed through control circuit. Then fed to control switches as gate signals [5].

4.1. Sine + 3rd Harmonic PWM Technique

The idea of Sine+3rd harmonic modulation technique is based on the fact that the 3-phase inverter-bridge feeding a 3-phase ac load does not provide a path for zero-sequence component of load current. Only three output points are brought out from a three-phase inverter-bridge. These output points are connected to the three supply terminals of the load. Such an arrangement does not cause any confusion for the delta connected load but for a star connected load the neutral point remains floating. However for a balanced, three-phase, star-connected load this should not be a drawback as the fundamental component in the load phase voltage is identical to the fundamental component of inverter's pole voltage[6]. In fact, the floating neutral point has the advantage that no zero sequence current (which includes dc, third and integer multiples of third harmonics) will be able to flow through the load and hence even if the pole voltage is distorted by, say, 3rd and integral multiples of third harmonics the load side phase and line voltages will not be affected by these distortions. Accordingly a suitable amount of third harmonic signal is added to the sinusoidal modulating signal of fundamental frequency. Now, the resultant waveform (modified modulating signal) is compared with the high frequency triangular carrier waveform. The comparator output is used for controlling the inverter switches exactly as in SPWM inverter. the low frequency component of the pole voltage will be a replica of the modified modulating signal provided (i) The instantaneous magnitude of the modified modulating signal is always less than or equal to the peak magnitude of the carrier signal and (ii) the carrier frequency is significantly higher than the frequency of modulating signal[6].

The addition of small percentage of 3rd harmonic to the fundamental wave causes the peak magnitude of the combined signal to become lower than triangle wave's peak magnitude. In other words, a fundamental frequency signal having peak magnitude slightly higher than the peak magnitude of the carrier signal, if mixed with suitable amount of 3rd harmonic may result in a modified signal of peak magnitude not exceeding that of the carrier signal. Thus the peak of the modulating signal remains lower than the peak of triangular carrier signal and still the fundamental component of output voltage has a magnitude higher than what a SPWM can output with m = 1.0. Thus the fundamental voltage output by the inverter employing Sine+3rd harmonic modulation technique can be higher [6].

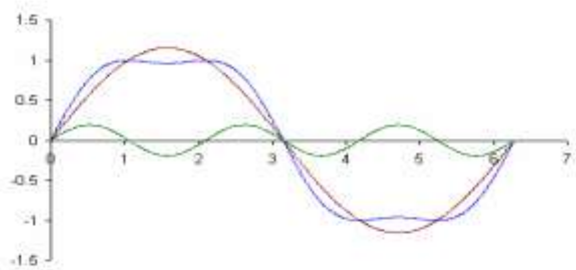


Fig3. The modulating signal for Sine+3rd harmonic modulation

V. SIMULATION RESULTS

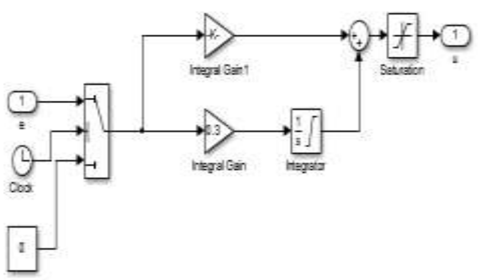


Fig4. PI Controller Circuit Diagram

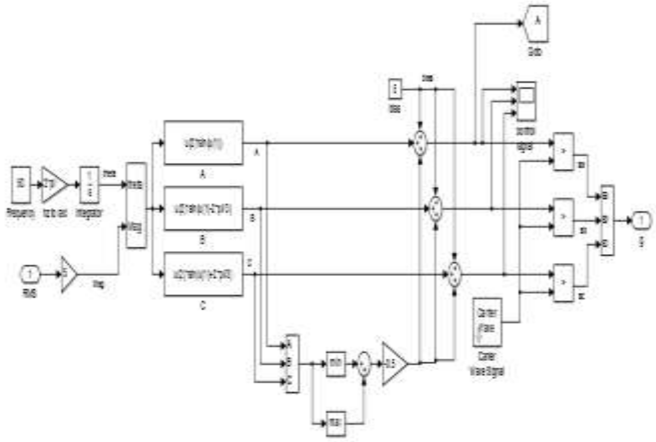


Fig5. Sinusoidal PWM with (sine plus3rd harmonic injection)

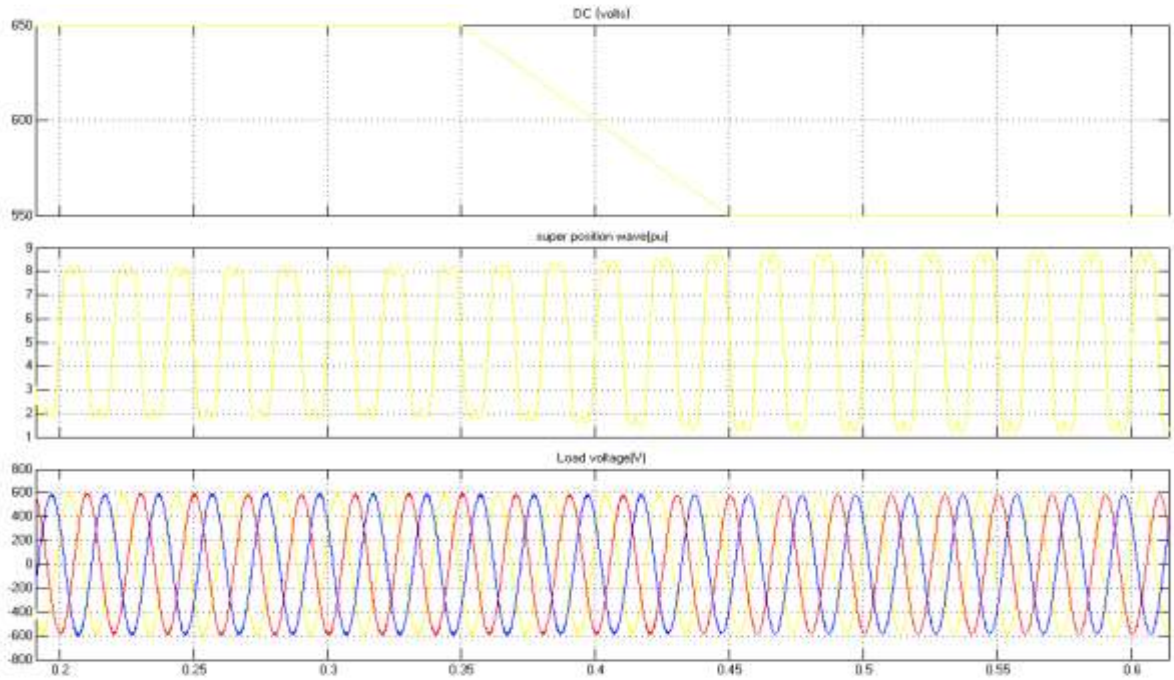


Fig6.(a) Input DC voltage with 8% voltage fluctuation, (b)Superposition wave (c)Stable output voltage (586.89V) .

From Fig6, (a) it show that voltage fluctuation of ±8% on peak magnitude, up to 0.35sec the DC voltage of more than the rated value. From scale0.35sec to0.4 sec the DC voltage decreased to below value of rated. After the scale 0.4sec to 0.45sedec the input DC voltage has decreased up to 8% less value than rated value. In fig6 (b)show the superposition wave(pu), its value up 0.35sec has constant magnitude after the scale from 0.4 to 0.45 sec superposition wave magnitude increase to such that the output voltage maintained constant magnitude. By using spwm method the results are supported to validate the proposed work.

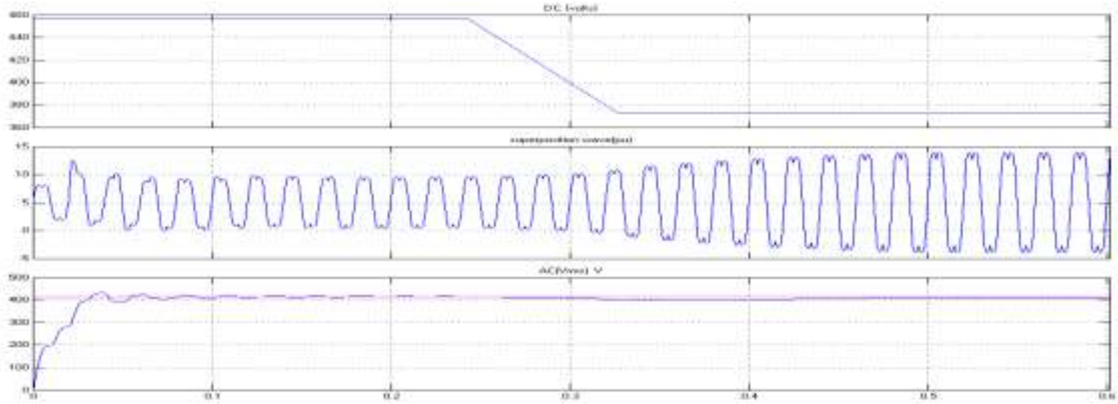


Fig7. 3level inverter (a) Input DC voltage with 10% voltage fluctuation, (b) Superposition wave (c) output voltage (Vrms) with 3kw load static load.

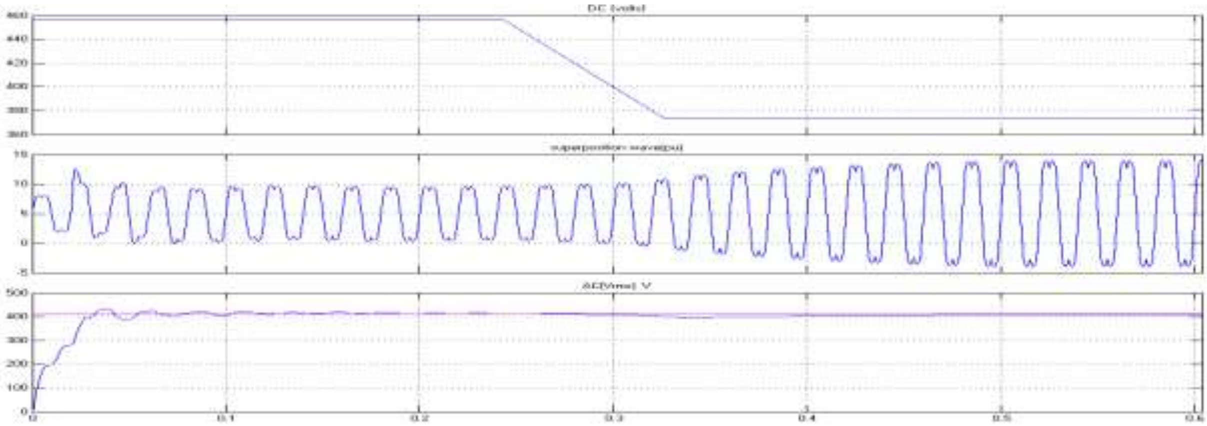


Fig8. 3level inverter (a) Input DC voltage with 10% voltage fluctuation, (b) Superposition wave (c) output voltage (Vrms) with 5kw static load.

From fig7&8, results are observed that the constant output voltages (Vrms),Even though input DC voltages are 10% fluctuation condition with static resistance load of 3kw and 5kw was an examined for three level inverter.

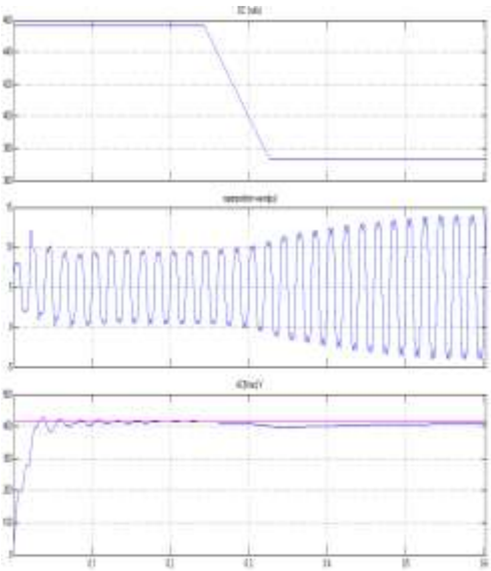


Fig : 9

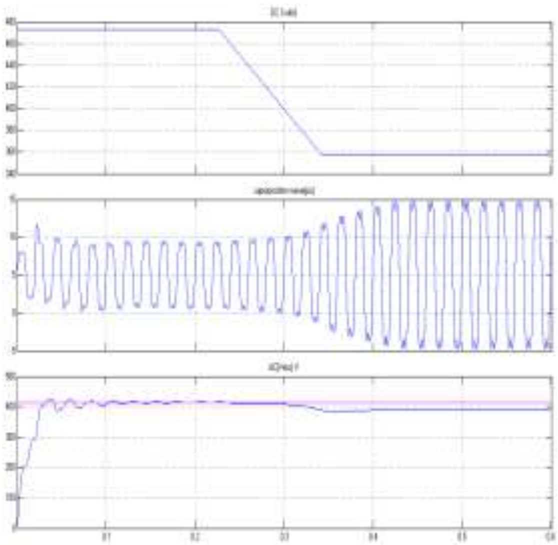


Fig : 10

Fig9. 5 Level Inverter
(a) Input DC voltage with 10% voltage fluctuation,(b) Superposition wave (c) output voltage (Vrms) With 3kw load static load
Fig10. 5 Level Inverter
(a) Input DC voltage with 14% voltage fluctuation, (b) Superposition wave (c) output voltage (Vrms) with 5kw load static load

From fig9&10, results are observed that the constant output voltages (Vrms),Even though input DC voltages are 14% fluctuation condition with static resistance load of 3kw and 5kw was an examined for five level inverter. In fig10(c) the output voltages is maintained constant magnitude with input DC voltages are 13% to 14% fluctuation condition with static resistance load, from fig9&10 (c) we analysis that by using PI control technique with spwm the obtained results are supported to up 13% to 14% input DC voltage fluctuation conditions, after scale 0.4sec the output voltages is not maintained constant and fluctuation conditions.

In the fig 11. Simulation Results are an analyzed that the time scale up to 0.3sec, an Induction motor rotor speed is constant and fluctuating nature for 5.4h.p induction motor load. After 0.3sec the motor speed is maintained constant as shown in fig11(b) and fig(c) respectively, the results are an examined that the output voltage Vrms is maintained constant. Table1, shows the validated result in this paper.

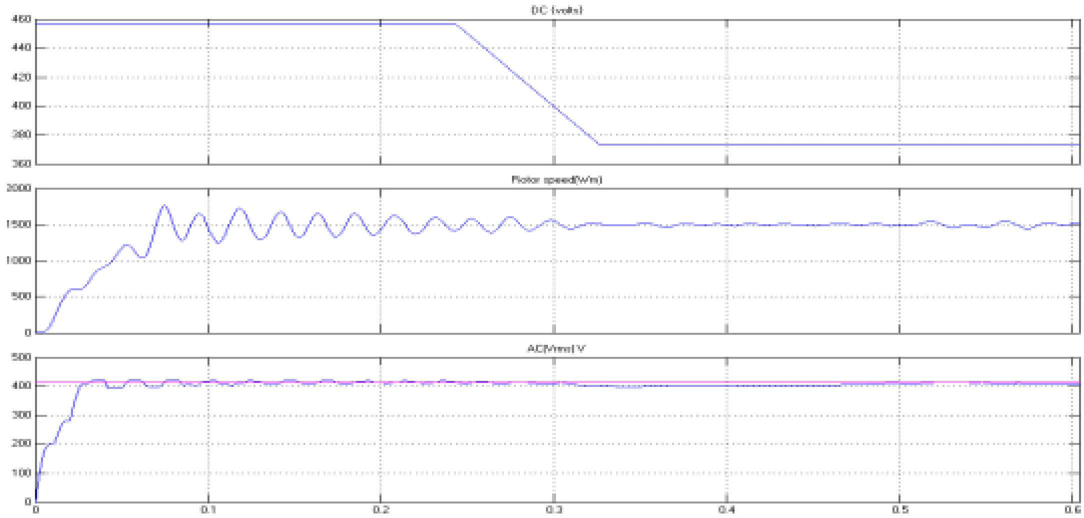
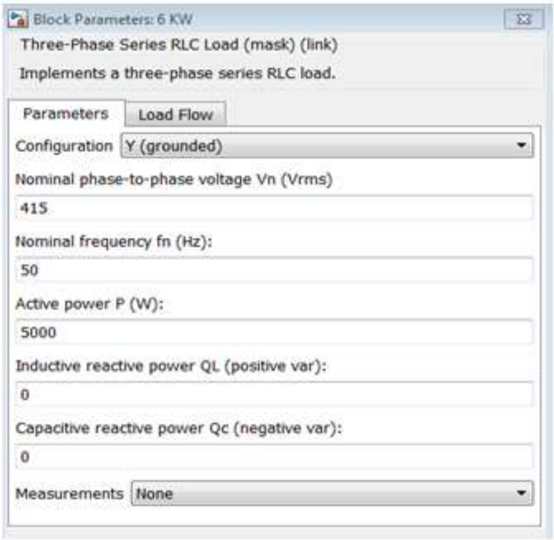


Fig11 .3level inverter (a) Input DC voltage with 10% voltage fluctuation, (b) Rotor speed of an asynchronous induction motor (c) output voltage (Vrms) with Dynamic load.

Table :1

Input DC voltage	Percentage (%)of flutuation	Stable output voltage(Vrms)
373.5(V)-456.5(V)	10	415
356.9(V)-473.1(V)	14	415



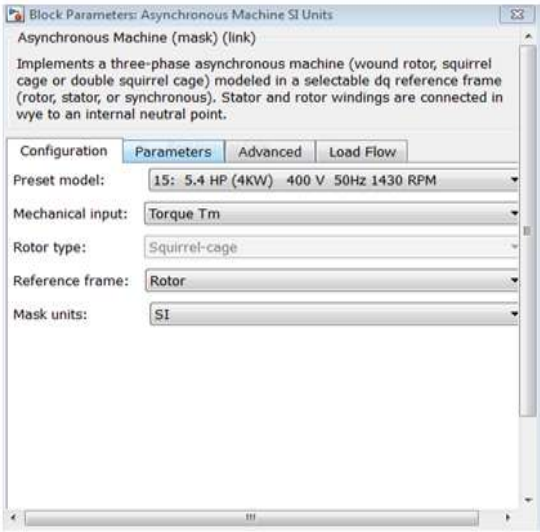


Fig 12.Static (Resistive) Load Parameters **Fig13.Dynamic Load Parameters**

VI CONCLUSIONS

In this paper, the proportional Integral (PI) control method which combined the improvement on voltage utilization factor through the superposition of third harmonic wave with voltage feedback control was proposed with validated results for static and dynamic load conditions, and it was applied to the three levels and five level inverters. Features of this control are to control the superposition ratio with the high amount fluctuation of the DC voltage. The improvement in the control performance is considered, and reduction of the capacity of the common-mode filter and electrolytic capacitor -less of the DC link for nonlinear loads will be examined. In this paper we confirmed the absorption of DC voltage fluctuations of about 14% was examined, 3,5Level cascade connection multilevel inverters with SPWM and static load conditions and 5HP dynamic load. In the future, we intend to focus on further reduction of output voltage distortion and improvement of the voltage control characteristics for dynamic loads.

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