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European Journal of Advances in Engineering and Technology, 2015, 2(7): 76-81

Research Article ISSN: 2394 - 658X

Dynamic Evolution Controller for Single Phase Inverter by Single Switch Control

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ABSTRACT

This article proposed a new single switch control based single phase inverter using dynamic evolution controller. Single switch control technique reduces the losses which is occurs during switching operation of an inverter and also minimize the cooling equipment cost for control switches. An inverter is a non-linear time invariant system; hence DEC makes it suitable, robust, large range over conventional control methods by its simplicity. In this paper, DEC simulates in MATLAB on single phase inverter for resistive, inductive and capacitive load by single switch control or varies the dc voltage according the required output voltage of inverter. Harmonics is also compared with IEEE519 harmonics standard.

Key words: Dynamic Evolution Controller (DEC), Single Phase Inverter, Pulse Width Modulation (PWM), Single Switch Control

INTRODUCTION

Power inverter [1-3] is a most important device in daily life in many power applications like dc to ac conversions [4-5], UPS (uninterrupted power supply) [6], inter-grid connections [7-9], renewable energy [10-11], electrical drives [12], induction heating [13] and other industrial applications [14]. An inverter should be provided the good quality of ac power supply for any type of load. Some time, condition of good quality ac supply increases the losses in system by continuously switching [15]. These losses are play important role to affect the operation of conversion switches semiconductor property. On high power high losses in switches require cooling for safe zone operation which increases the manufacturing cost of the system. In this article, operation of switching and inversion are separately control to reduce the losses by switching.

Many control techniques are proposed to control the operation of inverter in recent year where some technique based on non-linearity and some based on linear model with several assumptions. Some conventional controllers based are on linear theory [16-18], assumed that inverter is working linear for a small region. Other control methods like fuzzy logic [19-20], predictive control [21], slide control method [22-23], dq control technique [24] are based on non-linearity. These methods have several disadvantages in control the output.

A new controller based on dynamic evolution technique is proposed to control the output of inverter [25-26]. This controller is feasible to control the inverter output by single switch because the control function has a part of dc input supply. DEC is less calculative, fast responding and large range of operation make it superior over conventional controllers. Here the output of inverter gives a less harmonics with good quality of ac power supply according IEEE519 harmonics standard.

DYNAMIC EVOLUTION CONTROLLER

Basic Principle

The generalized form of DEC that “The difference between the output system and the reference input, which is denoted by error state, must be reduce to zero all the time, regardless, whether the disturbance is present or not”. This basic assumption is control the error state of the system and reduces to zero by forcing to follow a specific path with increase of time. This specific path is selected an exponential decay function shown in Fig. 1 for reduce the dynamic characteristics (Y) of the system to reduce to zero i.e. Y = 0.

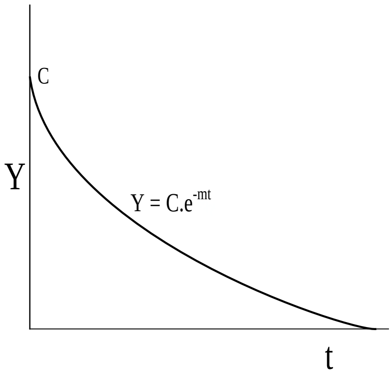


Fig. 1 Exponential decay function

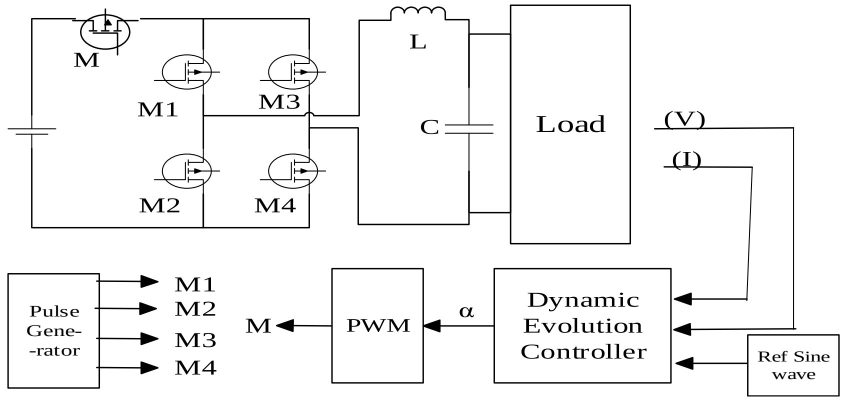


Fig. 2 Schematic control loop diagram

Application of DEC on Single Switch Controlled Single Phase Inverter

In a single phase bridge inverter four MOSFET switches are using to control and inversion for sine ac output. Four switches continuously switching according the switching frequency and switching losses are continuously happen. For reduce the losses, operation of switching and inversion is separated. Here inversion operation simply control by a pulse generator according the output frequency. As shown in Fig. 2, the inversion frequency is very less reduces the losses in two layer inverter. A controllable switch placed in series with dc supply and its control by DEC.

Here output of inverter divided into two parts: positive part and negative part. Positive part obtains by ON condition of switch M1 and M4 while M2 and M3 in OFF condition. For negative part output reverse condition is apply on all switches. In positive half cycle control switch M is ON while M1 and M4 also ON then output is given as:

$$V_{dc} = L\frac{di}{dt} + V \qquad (6)$$

When switch M in OFF state while M1 and M4 in ON state the output voltage is given by

$$0 = L\frac{di}{dt} + V \qquad (7)$$

Apply the voltage-second equation on equation (6) and (7) for a complete cycle for find out the dynamic characteristics of the system. Volt-sec equation for equation (6) and (7) is given respectively:

$$(V_{dc}).t_{on} = (L\frac{di}{dt} + V).t_{on} \qquad (8)$$

$$0 = (L\frac{di}{dt} + V).t_{off} \qquad (9)$$

The overall equation for this state is finding by adding the equation (8) and (9) as follow:

$$(V_{dc}).t_{on} = (L\frac{di}{dt} + V).(t_{on} + t_{off}) \qquad (10)$$

And $$T = t_{on} + t_{off} \qquad (11)$$

$$\alpha = \frac{t_{on}}{T} \qquad (12)$$

Here t_{on} is on time, t_{off} is off time, α is duty cycle and T is switching time period for switch M. from equation (11) and (12), equation (10) can be written as:

$$V = \alpha.V_{dc} - L\frac{di}{dt} \qquad (13)$$

In second state control switch M work similar like state one but this output is inverted by switch M2 and M3 so dynamic characteristics equation for negative half cycle is given as:

$$V = -\alpha.V_{dc} - L\frac{di}{dt} \qquad (14)$$

To apply the DEC from equation (1) the error state is

$$Y = k.V_{err} \qquad (15)$$

Where k is proportional constant and should be a small fractional number. V_{err} is defined the voltage error as follows:

$$V_{err} = V_{ref} - V \qquad (16)$$

Similarly the derivative equation of DEC as follows:

$$k.\frac{dV_{err}}{dt} + m.k.V_{err} = 0 \qquad (17)$$

Equation (17) can be written as:

$$k.\frac{dV_{err}}{dt} + m.k.V_{err} = V_{err} - V_{err} \qquad (18)$$

Rearrange the equation (18) as follows:

$$k.\frac{dV_{err}}{dt} + (m.k.-1).V_{err} = -V_{err} \quad (19)$$

From equation (16) put the value of V_{err} in equation (19) as follows:

$$k.\frac{dV_{err}}{dt} + (m.k.-1).V_{err} = V - V_{ref} \quad (20)$$

Put the value of V from equation (13) to equation (20) as:

$$k.\frac{dV_{err}}{dt} + (m.k.-1).V_{err} = (\alpha.V_{dc} - L\frac{di}{dt}) - V_{ref} \quad (21)$$

Rearrange the equation (21) and get the control function as follows:

$$\alpha = \frac{k.\frac{dV_{err}}{dt}+(m.k.-1).V_{err}+V_{ref}+L\frac{di}{dt}}{V_{dc}} \quad (22)$$

For second state, same equation (22) applies for control state because switch M vary the dc level between 0 and V_{dc}. Equation (22) calculate the appropriate value of duty cycle for the inverter. This duty cycle α is function of V, V_{dc} and i. Here V= output voltage of inverter, V_{dc} =input dc voltage of inverter and i = inductor current of inverter. Here the duty cycle can represent as $\alpha(V,V_{dc},i)$ for an inverter by using these above parameter we can calculate the desire control desire signal $V_{control}$ for inverter. The PWM signal generated by comparing the signal level control $V_{control}$ with a repetitive waveform of saw tooth type with constant peak and constant frequency shown in Fig. 3. Saw tooth wave frequency is remains constant for complete operation of inverter so DEC work on constant switching frequency for all operation. Therefore, design of filter circuit is easy for constant switching frequency and no need to modify the filter at inverter operation.

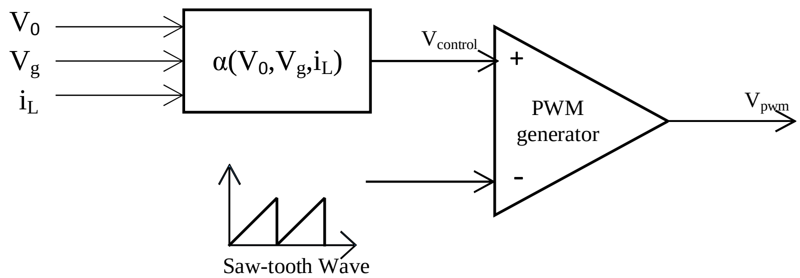


Fig. 3PWM signal generator

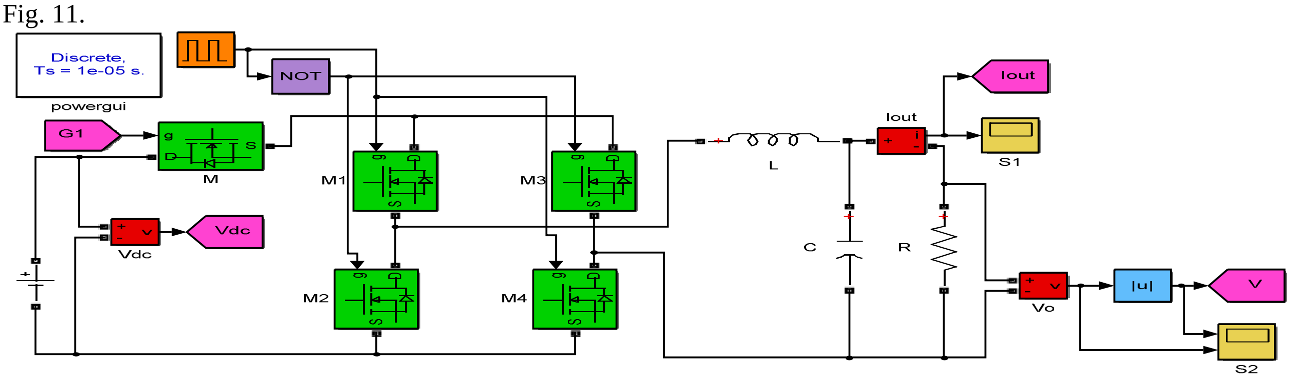
Table -1 Circuit Parameters

Parameters	Value
DC source voltage	350 V
Reference voltage	325 Peak, 50 Hz
Resistance	32.5 ohm
Filter inductance	10 mH
Filter Capacitor	10 uF
Switching Frequency	100 kHz
Supply Frequency	50 Hz
m	10000
k	0.01

SIMULATION AND RESULTS

Proposed controller simulates in MATLAB/Simulation version 2014a on a single phase inverter. Simulation model of DEC with single phase inverter is shown in Fig. 4. One switch M only connected with DEC to reduce the size of control circuit and other four switches connected with simple pulse generator for inversion in ac because switch M control the dc between 0 to V_{dc} level. A simple LC filter is connected after the inversion switch to filter the voltage form switching frequency to power frequency. Here comparison between reference and output by an absolute block is uses because switch M is unidirectional for complete operation. DEC calculates the value of duty cycle and this value compares with a saw tooth wave to generate the pulse for switch M. In Table 1 circuit parameters and components value are given.

First this system tested on resistive load that voltage and current output shown in Fig. 5 and 6 respectively. Inverter output voltage has small disturbance in each cycle due to filter capacitor not completely discharge before next cycle. This system also tested on inductive and capacitive load by insert an inductor and a capacitor in series with load resistance respectively. The voltage and current for inductive and capacitive load is shown in Fig. 7-10. The quality of output is permissible according to IEEE 519 harmonics standard and proved by FFT analysis shown in Fig. 11.



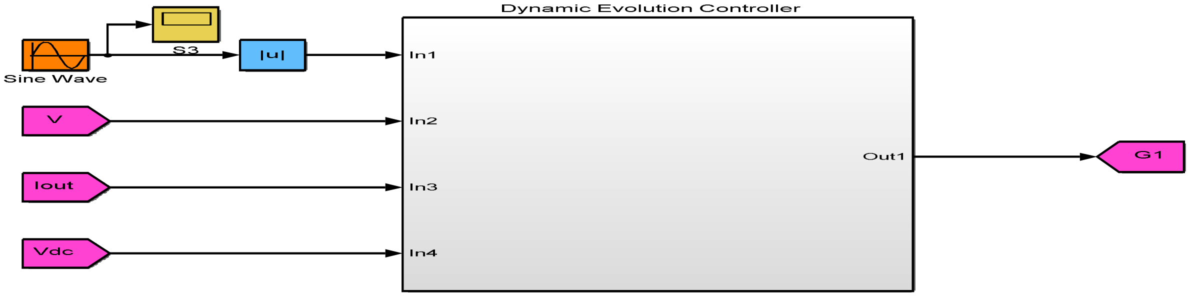


Fig. 4 Simulation in MATLAB

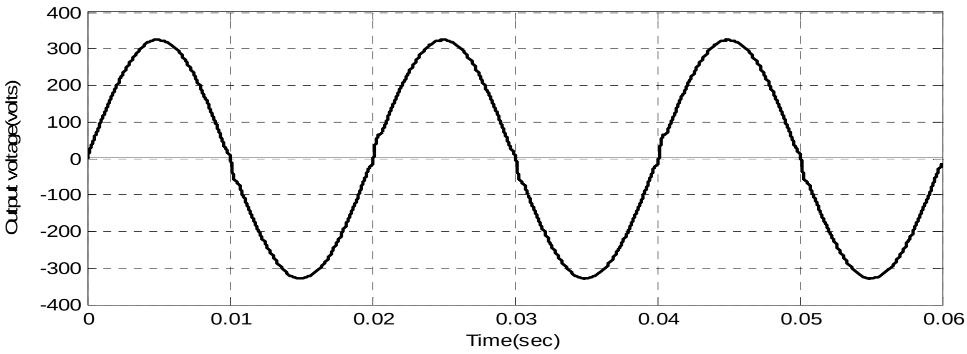


Fig. 5 Output voltage of inverter

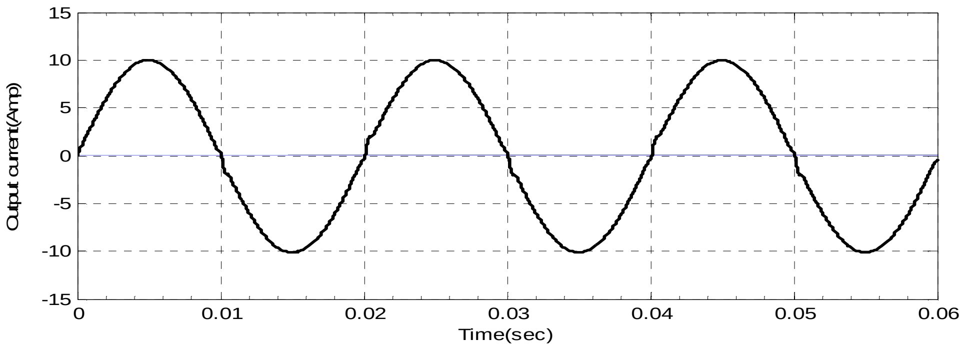


Fig. 6 Output current

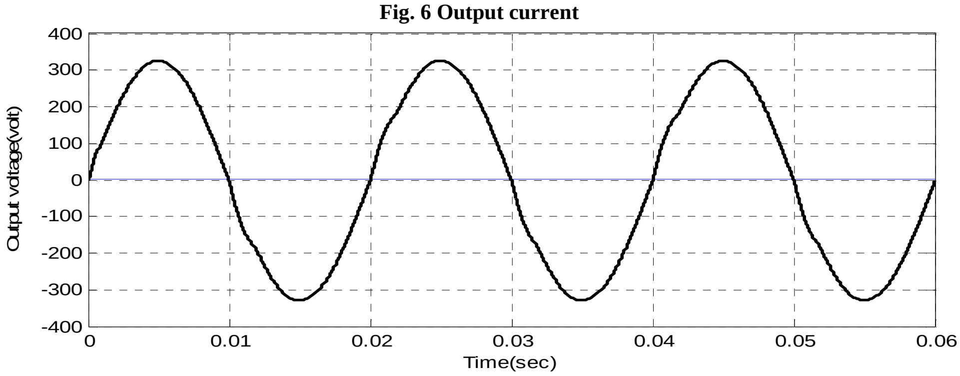


Fig. 7 Output voltage for inductive load

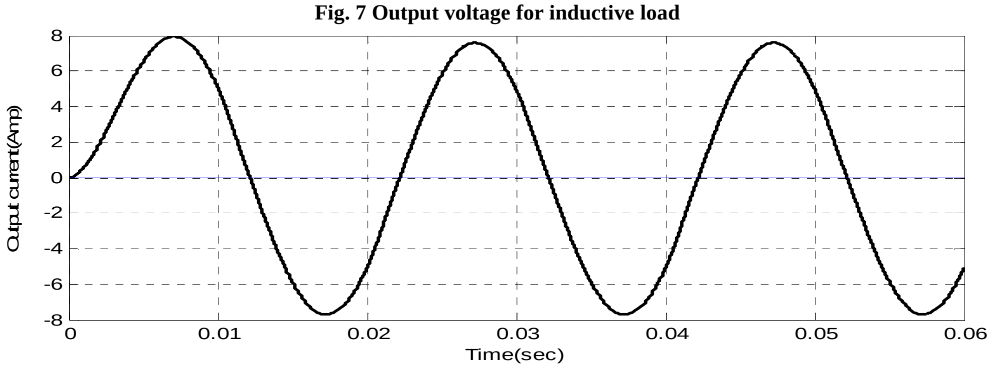


Fig. 8 Output current for inductive load

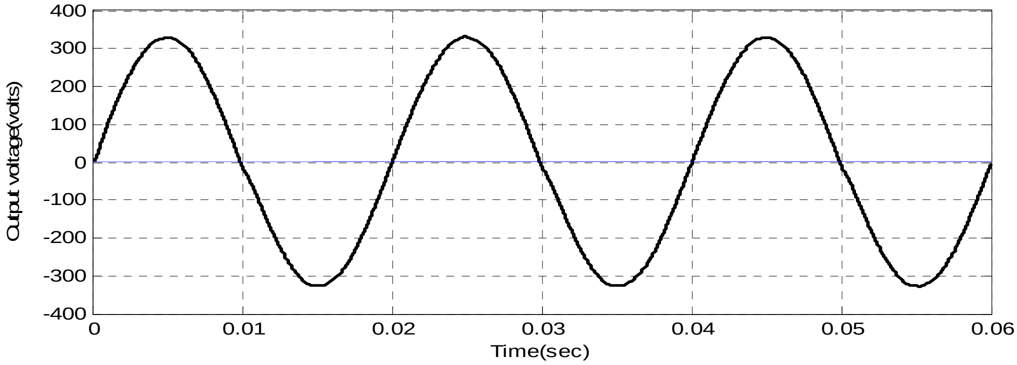


Fig. 9 Output voltage for capacitive load

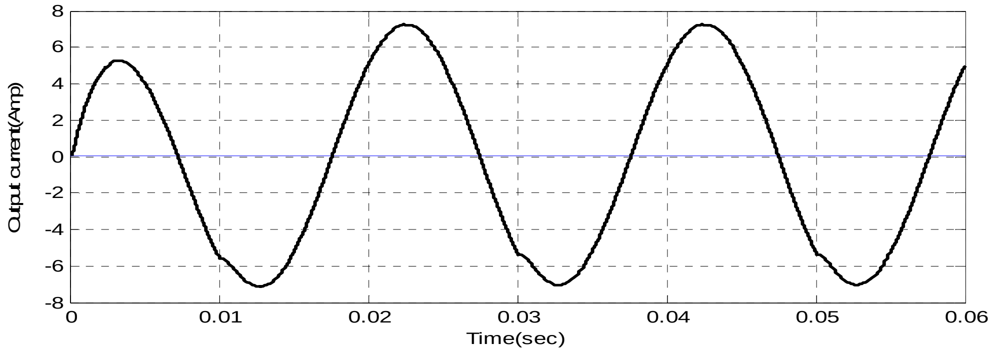


Fig. 10 Output current for capacitive load

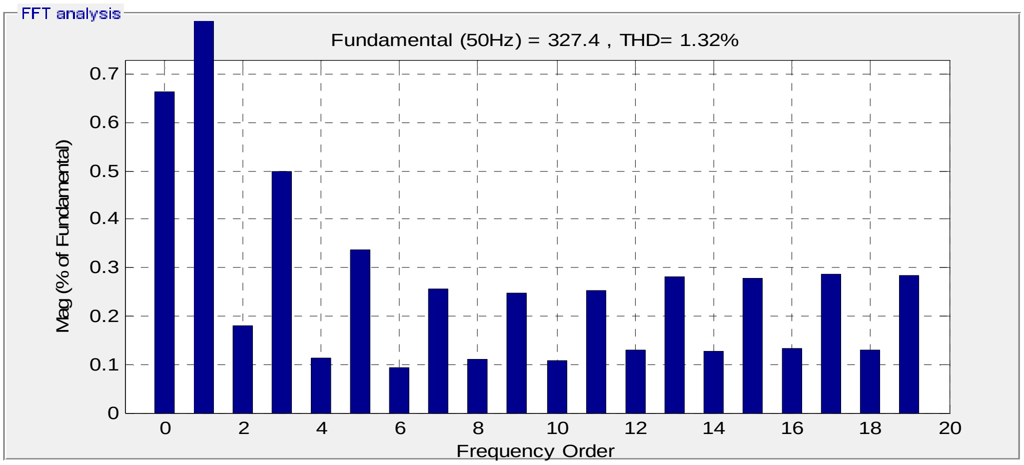


Fig. 11 FFT analysis of output voltage

CONCLUSION

A new control theory discusses for control the single phase inverter output over conventional control methods. This method is easy to design, calculate and less in complexity for non-linear, time variant systems. Single switch control is reduce the switching losses in inverter switch i.e. cooling problem is eliminate from inverter and it reduce the extra cost of cooling equipment. DEC is successfully control the output by single switch and it is also applicable for inductive and capacitive load. The inverter output quality is analysis by harmonics standard and it is within limit according the IEEE519 harmonics standard.

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