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Grid Interconnection of Renewable Energy Sources Using Modified One-Cycle Control Technique

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Abstract : **Renewable energy sources are gaining importance these days owing to the fact of the ever increasing electric energy demand which could not be met by the non-renewable sources of power generation due to their depletion at a very fast rate. Hence, renewable sources of energy are interconnected with the existing grids to increase the power capability. This paper presents a modified one cycle control technique to control the switches used in the three phase four leg converter used as the interface converter to interconnect the wind energy conversion system(WECS) to the existing grid by which it overcomes the problem faced by the one-cycle control while operating during light load conditions and also helps to minimize the load voltage and current harmonic contents to a very low value. The simulation is carried out using MATLABSIMULINK and the output waveforms are observed.**

Keywords : **Grid, Grid Connected Converters, Non-Renewable Sources Of Energy, One Cycle Control Technique, Modified One-Cycle Control, Renewable Sources Of Energy, WECS.**

I.INTRODUCTION

The Electric Power System (EPS) consists of three major components which are generation, transmission and distribution. Electric power is generated at power stations predominantly by synchronous generators that are mostly driven by hydro or steam turbines. Hence, the electric power generated at any such station usually has to be transmitted over a great distance, through transmission systems to distribution systems. This is illustrated in the one-line diagram of the power system shown in figure1.

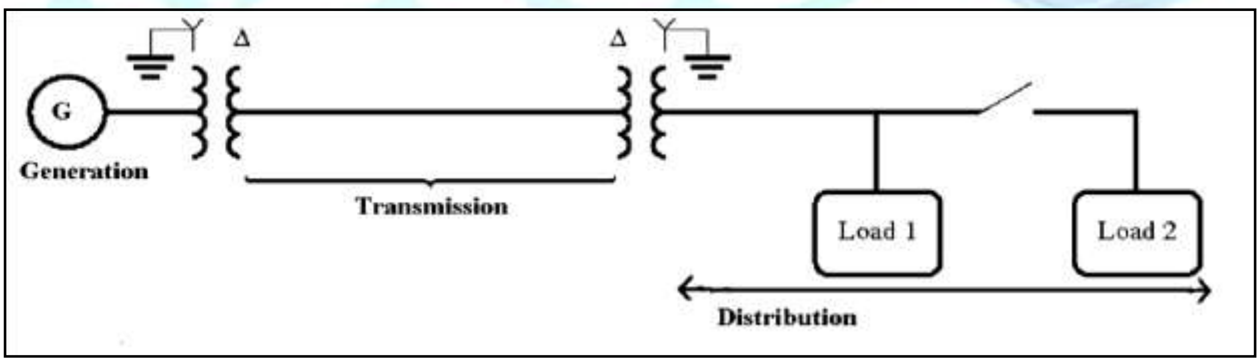

Fig1. One-Line Diagram Of The Power System

The distribution networks distribute the energy from the transmission grid or small/local Distributed Resources(DR) to customers. The three components i.e. generation, transmission and distribution have different influences, individual and sometimes common on the level of the quality of delivered electrical energy. There are many issues involved, such as the maintenance of power apparatus and system, the stability of the operation system, faults , distortions, loads non-linearities etc. The impact of failure within one component is observed on the whole performance of the power system. For example, a failure in the generation component may lead to failure in the transmission system and in a consequent load loss in distribution. Some of the problems are related to power transmission systems and some of them to power distribution systems but all are fundamental from the perspective of quality of delivered power. Sometimes faults in the system may lead to unbalanced system where the voltage or the current in one phase becomes unbalanced. During this condition the unbalanced currents flow in the neutral.

II.SYSTEM DESCRIPTION

The proposed system consists of a non-conventional source i.e. WECS connected to the dc-link of a gridinterfacing converter as shown in figure 2. The voltage source inverter is a key element of a DG system as it interfaces the non-conventional energy source to the grid and delivers the generated power. The nonconventional source may be a DC source or an AC source with rectifier coupled to dc-link. Usually, the fuel cell and photovoltaic energy sources generate power at variable low dc voltage, while the variable speed wind turbines generate power at variable ac voltage. Thus, the power generated from these renewable sources needs power conditioning (i.e., dc/dc or ac/dc) before connecting on dc-link [1]–[3]. The dc-capacitor decouples the RES from grid and also allows independent control of converters on either side of dc-link.

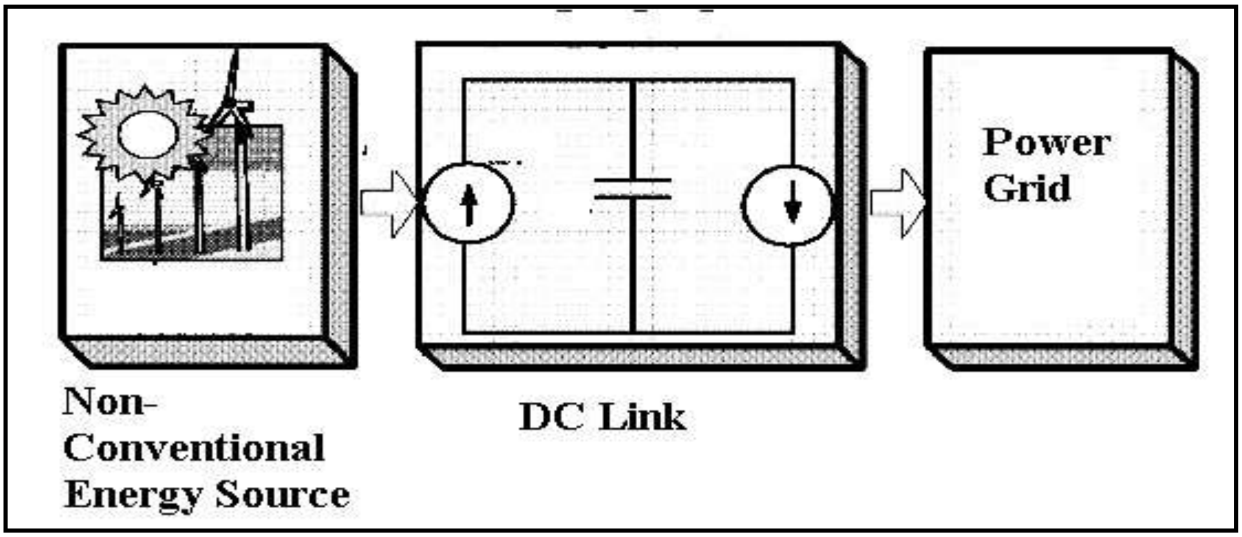

Fig.2 Equivalent Diagram Of The System.[10]

III.ONE-CYCLE CONTROL TECHNIQUE

OCC is the term used to describe a nonlinear control technique. Because switches are nonlinear systems, the idea is that a pulsed nonlinear control should provide faster dynamic response and reject input perturbations better than linear control since the nonlinear control matches the system. An input signal x(t) is passed through a switch and has an output y(t). The average value of y(t) is obtained by integrating y(t) and is then compared with a reference. As soon as the integrated value tends to reach the reference, a signal is sent to the controller from the comparator, which turns the switch off and resets the integrator to zero. The main idea is that if the duty cycle of the switch is controlled in such a way that in each cycle the integration of the chopped waveform at the switch output is exactly equal to the integration of the control signal then the output signal becomes instantaneously controlled within one cycle. This gives a faster response.

MATHEMATICAL ANALYSIS

Let a switch is described mathematically as a function k(t):

$$K(t) = \begin{cases} 1, 0 < t < Ton \\ 0, Ton < t < Ts \end{cases} \quad (1)$$

If the switch conducts for a period of time Ton and does not conduct for a period of time Toff, then its duty cycle is described by "D" and is given as

Duty Cycle, $D = \frac{Ton}{Ts}$ (2)

which is modulated by the control signal vref(t). The switch performs chopping action of the input signal x(t) to produce an output y(t) with the same frequency and width of the pulse being k(t), where x(t) acts as the envelope for y(t) as seen in the below figure3.

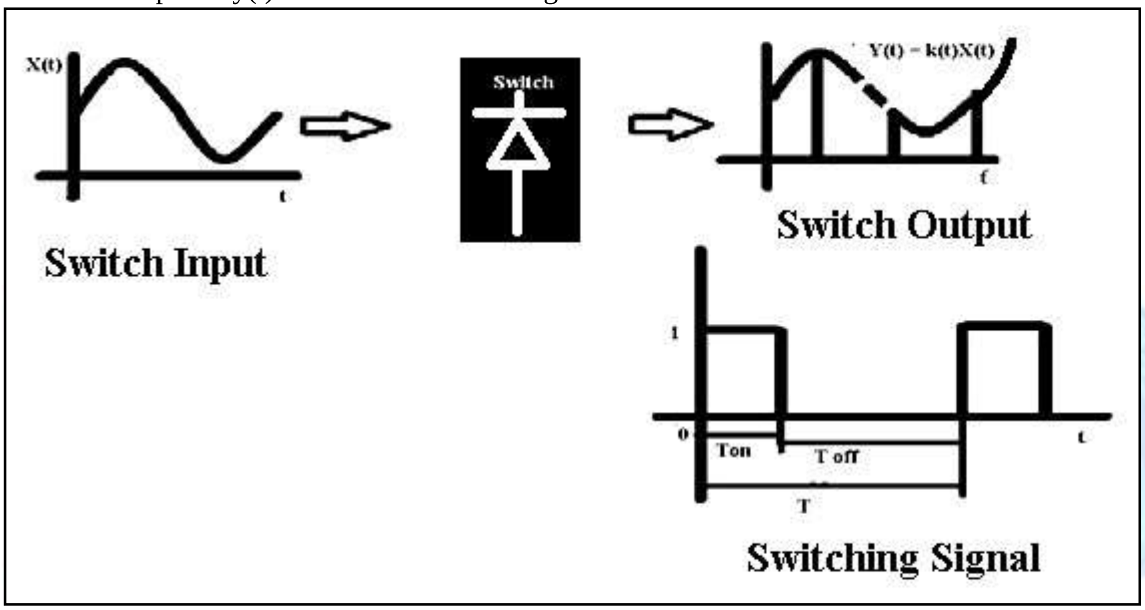

Fig 3.Switch Input, Output and Switching Signal.

For practical purpose it is assumed that the switch frequency fs is much higher than the frequency bandwidth of x(t) or vref(t), the effective output value y(t) is equal to the average value over a switch cycle:

$$y(t) = \frac{1}{Ts}\int_0^{Ts} x(t)dt \cong x(t)\frac{1}{Ts}\int_0^{Ton} dt = x(t)dt = x(t)Vref(t) \quad (3)$$

Thus, the output signal y(t) is a product of the input signal x(t) and the control vref(t) making the switch nonlinear. If the control signal is constant i.e .vref(t) = D then the output becomes Dx(t), as is the case in digital signal processing. For applications involving power processing, x(t) usually represents the power, while vref(t) is the signal to be amplified. Generally, the input power x(t) is constant, but in reality there are perturbations causing disturbances to the output y(t) also.

If the switch duty ratio "D" can be modulated such that in each cycle the integration of the chopped waveform at the output of the switch to be controlled is exactly equal to the integration of the control signal as shown below,

$$\int_0^{T\,on} x(t)\,dt = \int_0^{Ts} V\,ref(t)dt \quad (4)$$

Then the output signal becomes immediately controlled within one cycle which is the main principle of this technique i.e.

$$y(t) = \frac{1}{Ts}\int_0^{T\,on} x(t)dt = \frac{1}{Ts}\int_0^{Ts} V\,ref(t)\,dt = V\,ref(t). \quad (5)$$

Due to the switching frequency fs, being much higher than the time-varying reference voltage, it can be seen as constant in one period, thus the above equation can now be written as:

$$y(t) = V\,ref \quad (6)$$

Thus, the switch is able to reject any input disturbances since it does not depend on x(t) and is able to pass vref in a linear manner, thereby making a non-linear switch into a linear switch. One-cycle control technique can solve such type of problem. One-cycle control technique has fast transient response and good tracking performance. However, the schemes based on OCC exhibit instability in operation when the magnitude of the load current falls below a certain level or when the converter is operating in the inverting mode of operation [4], [5]–[8], [9].

IV.MODIFIED OCC TECHNIQUE FOR THECONTROL OF GRID INTERFACING INVERTER

In this technique, three fictitious current signals, which are proportional to the respective phase voltages and in phase with three utility voltages, are synthesized. These current signals are added to the actual source current signals, and their sum is compared with the saw-tooth waveform to generate gating pulses for the converter switches. The proposed technique requires neither the knowledge of 60^O angular sectors of input voltage nor the service of additional multiplexers, gate distribution logic, and other additional analog and digital logic circuits, as in [1], [2], and [9]. Moreover, it does not need to select positive and negative peak voltages as reference current vectors, as required in [5]. Detailed simulation studies are carried out to verify the effectiveness of the proposed scheme.

The control block diagram for a modified three phase OCC-based converter is shown in figure4. The dc link capacitor voltage V_o is sensed and compared with the desired value V_o^*. This error is processed by a proportional–integral (PI) controller to generate a signal V_M. Therefore, at steady state, when V_O is equal to V_O^*, the signal V_M is proportional to the real component of the source current of the converter. Using the signal V_M, a bipolar saw-tooth waveform of amplitude V_M and having a time period of T_S is synthesized. This is achieved by integrating the signal V_M with a time constant $T_{i.}$ *TS* is the time period of clock pulses, which resets the integrator. The switching frequency of the converter devices is the same as that of the frequency of the clock pulses. At every rising edge of the clock pulse, switches *S*2 and *S*4 are turned on, and the source (inductor) current increases. The output of the comparator, which compares the inductor current with the saw-tooth waveform, determines the turnoff instant of *S*2 and *S*4, and the turn-on instant of *S*1 and *S*3. When *S*1 and *S*3 are turned on, the sensed boost inductor current signal reduces.

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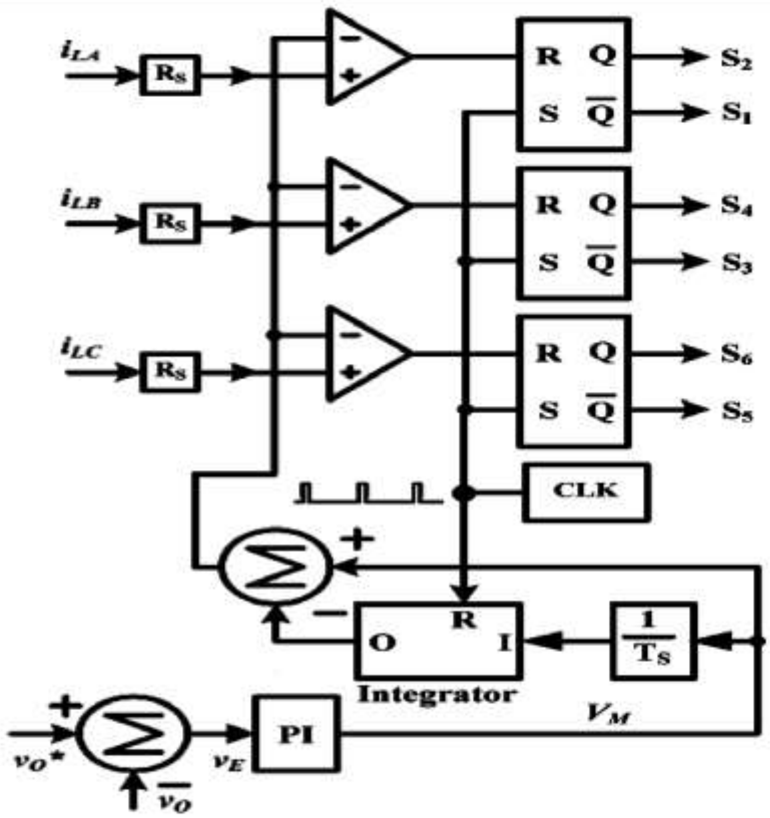

Figure4. Control Block Diagram For Modified Three Phase OCC-based Converter[6]

V.SIMULATED PERFORMANCE

In order to analyze the performance of the circuit, a model of the modified hybrid buck converter is simulated in MATLAB-SIMULINK and the output waveforms and various parameters are obtained

The simulated circuit for an interconnected gird system using Modified One Cycle Control technique is show in figure5.

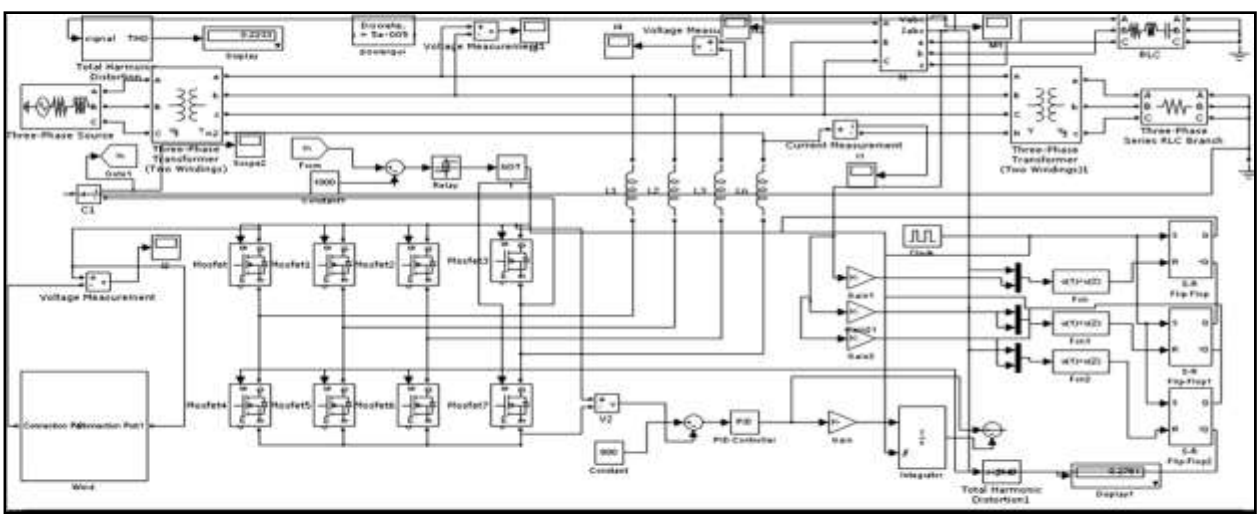

Figure5. Interconnected Grid System Using MOCC Technique

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The system above consists of the Modified OCC Control Circuit which gives the pulses for the switches used in the three phase four leg grid interface converter. The corresponding output waveforms are shown in figure6 and figure7.

The output voltage at load end waveforms are

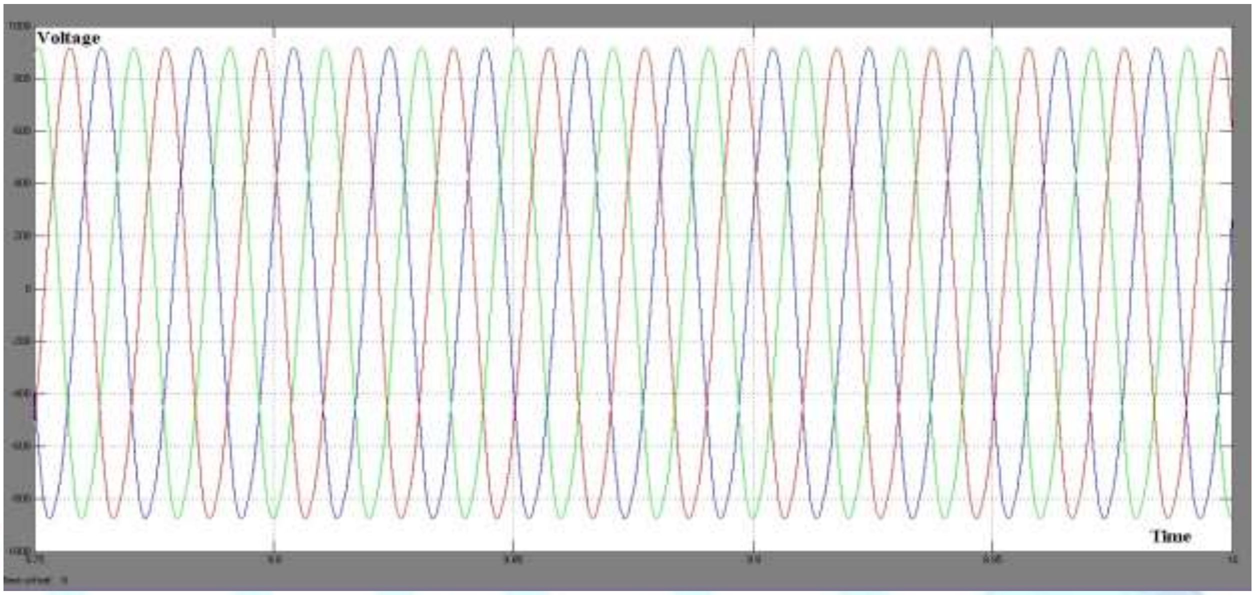

Figure6. Output Voltage Waveform At Load End Of The Interconnected Grid System Using MOCC Technique

The output current at load end waveforms are

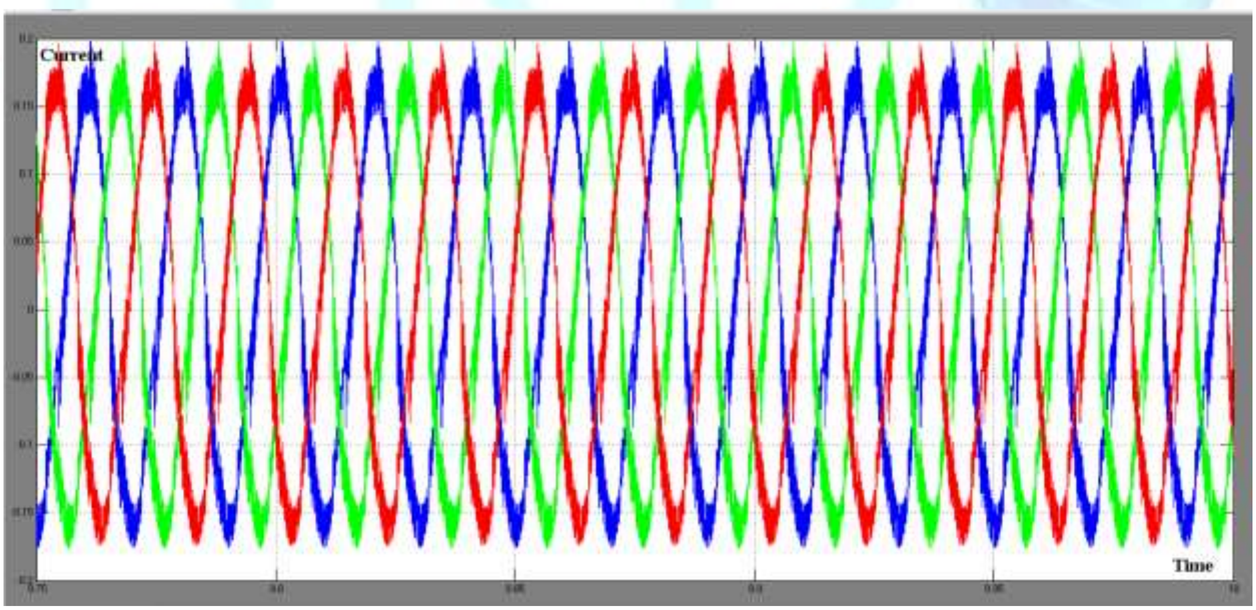

Figure7. Output Current Waveform At Load End Of The Interconnected Grid System Using MOCC Technique

VI.CONCLUSION

An efficient interconnected grid system using the modified one cycle control technique has been presented, which reduces the harmonic content in load voltage as well as load current to a great extent. This also improves the performance of the interconnected grid system. The Modified One-Cycle Control scheme has better functionality and harmonic elimination in the load voltage as well as the load current.

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