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Power Quality Enhancement of the Distribution Network by Multilevel STATCOM-Compensated Based on Improved One-Cycle Controller

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ABSTRACT There are several ways to reduce and compensate for voltage disturbances. One of the methods is to use a Multilevel STATCOM. Multilevel inverters are widely used in various parts of the power system and industry due to advantages, such as appropriate output waveform (voltage and current). There are numerous controllers for multilevel STATCOM control. One of the simple and economy controllers is the one-cycle controller, which is usually used in DC / DC and DC / AC converters. In this paper, a new structure is proposed to improve the performance of the one-cycle controller. Improvements include voltage sag and swell, voltage disturbances, harmonics, and short-term outages. To demonstrate the performance of the proposed controller, the multilevel STATCOM is also tested and compared with conventional PWM control. The simulation results show that multilevel STATCOM will correct the disturbances. Among the advantages of the proposed method are its simplicity, robustness, and flexibility, so that with one adjustment, the parameters of the control system can compensate for all the defects.

INDEX TERMS Multilevel STATCOM, one cycle control, PWM control, voltage disturbances, multi-bus system, voltage sag, voltage swell.

I. INTRODUCTION

Due to the increase in sensitive loads, paying attention to power quality problems is necessary. Failure to pay attention to these problems will cause great financial losses. Voltage stability is important in improving the safety and reliability of power systems and is one of the main factors in the power quality of networks [1], [2]. Reactive power compensation is an effective solution for stabilizing the voltage of the network. Among reactive power compensators, STATCOM equipped with a voltage source inverter has always been considered by researchers due to its considerable flexibility and controllability. This compensator has gained considerable popularity over the past decade due to power systems' support and dynamic voltage supply [3].

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Compared to a conventional two-level inverter, a multilevel inverter configuration has advantages such as a higher voltage level on the AC side and improved waveform under harmonic distortion [4], [5]. In the category of multilevel inverters, there are three dominant configurations: 1) clamp diode inverter [6]; 2) floating capacitor inverter [7], and 3) Integrated bridge H cascade inverter [8]. Compared to other topologies, it is possible to connect back to back in the clamp diode topology due to the common DC source, which leads to the input and output current waveforms approaching the sinusoidal state with a lower switching frequency and a smaller filter.

The STATCOM system injects current into the network from a common connection point, resulting in harmonic filtering, voltage control, power factor correction, neutral current compensation, and load balancing. STATCOM applications include reactive power compensation voltage conservation strategy in low voltage networks. Dynamic mixed compensation with thyristor switching capacitor (TSC) in the distribution system reduces power fluctuations in photovoltaic systems, increases the penetration of solar systems in the distribution system, and decreases voltage drop/increase/fluctuation. Fig. 1 shows a three-phase STATCOM using a three-level clamp diode structure in each phase and a three-phase phase voltage waveform.

In the past, various methods have been proposed to control STATCOM. The PI is a common two-loop control strategy for controlling STATCOM active and reactive currents. This control strategy establishes a connection between active and reactive currents [9]. The presence of an unbalanced voltage at the point of common coupling (PCC) leads to the emergence of a negative sequence current component, which worsens the control performance. Therefore, it is very difficult to maintain the PCC point voltage in the event of a small disturbance in the dc voltage link. It is also difficult to set PI controller parameters and requires complex mathematical modeling of the system under study. The PI controller parameters are set for the best performance within the normal operating range of the system. In the event of changes in network load and parameters and nonlinear network conditions, the PI controller may not work properly.

Various methods have been proposed to eliminate this problem in the design of the PI controller. Since all of these designs for PI controllers are based on the STATCOM linear model and the nonlinear static compensation model, the nonlinear control method is used directly without the need for linearization [10]. On the other hand, many previous methods may not be resistant to different operating conditions. Optimal linear control based on the quadratic linear regulator is proposed in [11]. A fuzzy PI control method has been proposed to adjust the PI control gains [12].

In multilevel converters, there is a significant increase in the number of components and the problem of voltage imbalance at different capacitor voltage levels. However, PLL service must generate the required reactive current or synchronize the PWM voltage waveform. Designs based on one cycle control became important because of their simplicity in the controller structure [13].

In the reference [14], the PWM method is compared with the one cycle control method, and its advantages are shown. Compared to PWM, this method has less error in the permanent state response and better response in the dynamic state, as well as it is very easy to understand, and it can be used as a switching method in many cases.

In this paper, by presenting an optimal control method in the compensating switching structure of STATCOM, switching pulses can be generated for different purposes. These goals can be achieved with a network voltage control approach against possible disturbances. In some cases, some circuit parameters may change momentarily, which can interfere with the proper functioning of the control system. By improving the proposed control structure, the control system can be sensitive to such phenomena. The second section is a study of STATCOM structure and STATCOM

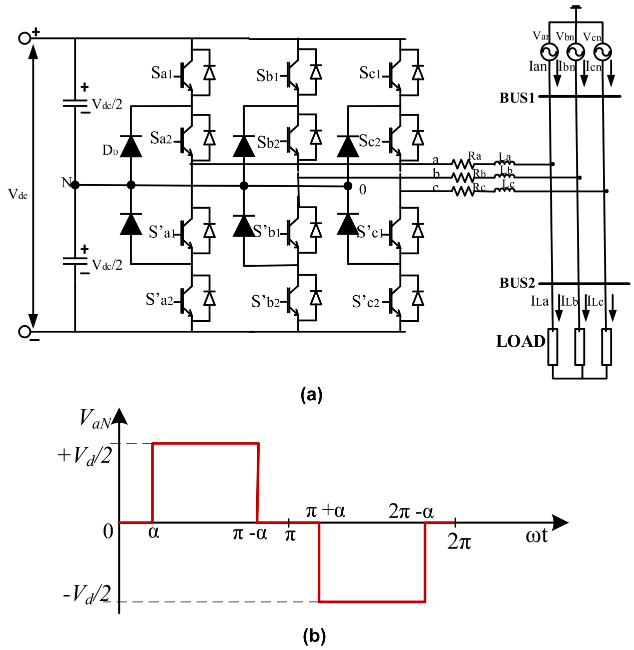

FIGURE 1. (a) Three-level clamp diode structure, based on STATCOM connected to network and load of the system and (b) three-level phase voltage waveform.

performance. STATCOM control methods and a comparison of the proposed method with other methods are presented in the third section. The fourth section deals with the design of the proposed one-cycle controller. The system simulation and the conclusion of the work are summarized in the fifth section.

- To propose a novel robust and flexible structure for enhancing the performance of the one-cycle controller;
- To investigate the performance of the proposed multilevel STATCOM controller in comparison with the conventional PWM approach;

II. STATCOM STRUCTURE AND PERFORMANCE

A. CONVENTIONAL STATCOM SYSTEM CONFIGURATION

The equivalent circuit of a typical STATCOM connected to the grid and load system is shown in Fig. 2, which includes a transformer with a parallel connection, a voltage source inverter, a low-pass filter, and a capacitor in the DC link. The governing relations are as follows:

$$\frac{di_{inva}}{dt} = \frac{1}{L_s}\left[V_{ia} - V_{ca} - R_s i_{inva}\right]$$
$$\frac{di_{invb}}{dt} = \frac{1}{L_s}\left[V_{ib} - V_{cb} - R_s i_{invb}\right]$$
$$\frac{d}{dt}V_{dc}^2(t) = \frac{2}{C}\left[V_{ia}i_{inva} + V_{ib}i_{invb} + V_{ic}i_{invc}\right] \quad (1)$$

where, V_{ia}, V_{ib}, and V_{ic} are the three-phase output voltages of STATCOM. V_{ca}, V_{cb} and V_{cc} are the three-phase voltage of the STATCOM connection bus. i_{inva}, i_{invb} and i_{invc} are STATCOM output three-phase currents, R_s and L_s are filter elements, C is the capacitance of the DC link capacitor, and V_{dc} is the DC link voltage. Since the STATCOM system is parallel to the network, the relationship between the load current and the network with the STATCOM current can be obtained according to Equation (2):

$$I_{L,a}(t) = I_{s,a}(t) + I_{inv,a}(t)$$
$$I_{L,b}(t) = I_{s,b}(t) + I_{inv,b}(t)$$
$$I_{L,c}(t) = I_{s,c}(t) + I_{inv,c}(t) \quad (2)$$

where *L, S,* and inv subtitles are for load, source, and inverter, respectively. When the voltage is low, the STATCOM injection current increases the network voltage, and when the voltage is high, the STATCOM injection current decreases the network voltage. Thus, to correct grid and flicker harmonics and other grid voltage disturbances, the STATCOM injection current must be such that it reaches a near-sinusoidal voltage consumer with a range of one per-unite.

B. THREE-LEVEL STATCOM BASED ON NPC

Multilevel clamp diode inverter can produce different levels of voltage waveform by clamp diodes and dc capacitors. This inverter can generally be configured as a three, four, five, or seven-level topology, which the three-level inverter is called a neutral point clamp inverter (NPC), as shown in Fig. 1. In the three-level arrangement, each leg consists of 4 switches, which according to Fig. 1, the switches are two complementary to each other ((S_{a1}, S'_{a1}) and (S_{a2}, S'_{a2})). Switches S_{a1} and S'_{a1} work in a complementary way, meaning that when one switch is on, the other must be off. The capacitor's midpoint is the inverter's neutral point, and the output voltage is measured relative to this point. DD control diodes are an advantage over dual-level inverters. The main function of these diodes is to maintain the DC voltage to generate the step output voltage and limit the voltage stress of the power devices.

The STATCOM of Fig. 1 can control the power factor or voltage at the load terminal by exchanging reactive power with the system by a three-level clamp diode inverter. To control the active and reactive power components of STATCOM, the magnitude and angle of the voltage at the STATCOM terminals must be controlled. In this paper, the magnitude and angle of the STATCOM voltage are adjusted based on the one cycle control technique presented in the next section.

C. STATCOM CONTROL AND SWITCHING METHOD

The controller is one of the most important parts of any system. Proper control can minimize system error performance. It will also reduce the number of system components, resulting in reduced system size and weight system maintenance costs. Simple control makes it easy to build a practical system in real space. STATCOM controller has the task of turning on or off each system switch at the appropriate time. For this purpose, the controller function can be divided into two or even three blocks. The first block is related to finding the reference signal, the second block is the error compensation strategy, and the switching method is the third control block. The second and third blocks are interconnected because the second and third blocks' function generates the reference current by a switching method at the output. PWM (pulse width modulation) method is one of the common methods in this section [15]. In the PWM method cycle, a high-frequency triangle waveform (carrier waveform) is compared with a reference signal.

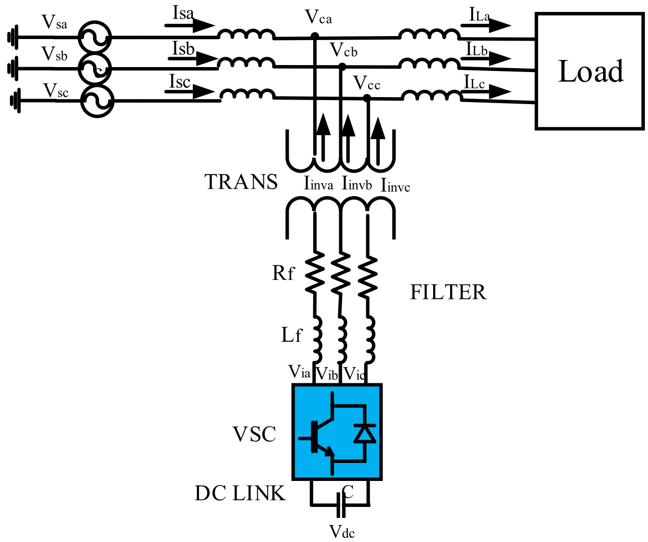

FIGURE 2. The equivalent circuit of a STATCOM connected to a grid and load system.

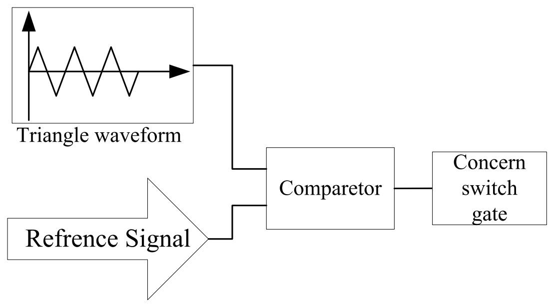

FIGURE 3. Structure and operation of PWM switching method.

Fig. 3 shows the structure and method of the PWM method. In the PWM method, any change in input voltage must be sensed at the output voltage and the output error reused at the input. This means slow dynamics in tracking the input voltage change and an undesirable transient response in the output voltage setting. This problem can be largely solved with one cycle control. One cycle control and its flexible program have less error than other methods. This nonlinear control method is used for DC / DC or DC / AC converters [16]–[18]. Its components are few and accessible, and any system with such a controller can be easily implemented in practice.

III. ONE CYCLE SWITCHING CONTROL METHOD

A. STRUCTURE AND OPERATION OF ONE CYCLE CONTROL

One cycle control in the term describes a nonlinear control technique. Since the switching system is nonlinear, the idea

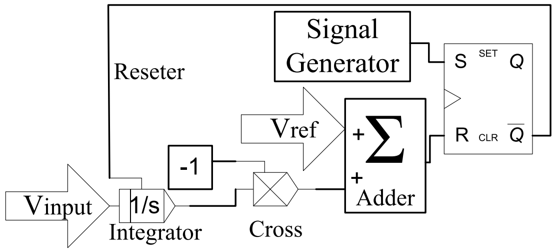

FIGURE 4. One cycle control structure.

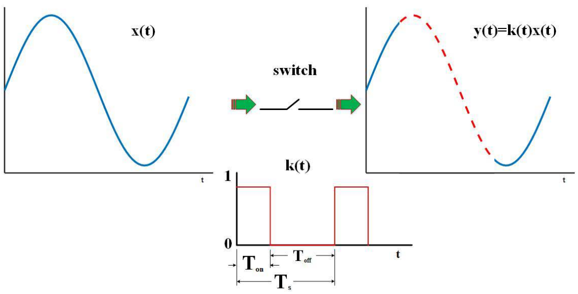

FIGURE 5. Input, output signals, and switch pulse.

is that the nonlinear pulse control should provide a faster dynamic response. The one-cycle control structure is shown in Fig. 4. This controller includes a self-tuning integral, an RS flip-flop generator, a comparator, and a clock pulse. In this controller, the switch goes through the integral in each switching cycle and turns on until the input voltage reaches the reference voltage. When the output value of the integral equals the reference signal, the flip-flop resets, resulting in the disconnect switch and the integral resets and is ready for the next cycle switch. Equation (3) shows the equality of the mean value of the waveform with the reference value. Since the value of the integral taken from the input signal is equal to the reference signal, the area under the input signal waveform in each switching cycle is equal to the controller reference signal. Therefore, the instantaneous control of the input signal is well achieved. As a result, the adjustable switch always follows the control reference, and the output voltage will be independent of the input voltage changes.

$$\frac{1}{T_s}\int_0^{t_{on}} v_G dt = V_{ref} \tag{3}$$

It is assumed that the gate command function $K(t)$ is defined as follows:

$$K(t) = \begin{cases} 1, & o < t < T_{on} \\ 0, & T_{on} < t < T_s \end{cases} \tag{4}$$

In which the interval of a switch is on T_{on} and the period of switching T_S is defined, the work cycle is equal to $d = \frac{T_{on}}{T_s}$. The method of generating the desired output signal from the input signal with the same frequency and pulse width can be seen in Fig. 5. $X(t)$ is the input signal and $Y(t)$ is the output signal.

B. PROPOSED ONE CYCLE CONTROL

The proposed switching method is based on the one cycle control mentioned in the previous section. Since in three-phase STATCOM, according to Fig. 1, each phase has two parts, negative and positive, the switches S_1 and S_1', S_2 and S_2' belong to phase a, the switches S_3 and S_3', S_4 and S_4' belong to phase b and the switches S_5 and S_5', S_6 and S_6' correspond to phase c. In this type of naming, by connecting the odd switches, i.e., S_1, S_3, and S_5, the positive voltage is injected into the secondary, and by connecting the even switches, i.e., S_2, S_4, and S_6, the negative voltage is injected. The symbol (') indicates the reverse switches. In the proposed method, the negative part injects a negative voltage, and the positive part injects a positive voltage into STATCOM. But this is part of the controller function, and more needs to be done to improve this approach.

1) FIRST IMPROVEMENT

To increase the speed in one cycle control (OCC), the output of the integrator can be multiplied by the coefficient of integration. By doing this, the integral is a function of the high-speed input voltage. This method is shown in Fig. 6.

2) SECOND IMPROVEMENT

To generate a reference signal, three signals are made up of three phases of sine voltage, which is expected to be equal to that value. These three signals have the same amplitude and 120-degree angle difference. These three signals are regularly compared to network voltages at each stage to obtain a control reference signal. To eliminate various disturbances, this signal needs to be corrected. But instead of modifying the reference signal, a better way is used in this article. Instead of improving the reference signal, several paths reset the flip-flop. The design of these routes is very simple, and only a few comparators are used. According to Equation (5), the first way to reset the flip-flop is to compare the three load voltages V_L, the mains voltage V_S and the desired V_{ref}.

$$\begin{aligned} FORS_1, S_3, S_5 &= \begin{cases} 1, & V_{ref} > V_s \ \& \ V_{ref} \leq V_L \\ 0, & V_{ref} \leq V_s \ \& \ V_{ref} > V_L \end{cases} \\ FORS_2, S_4, S_6 &= \begin{cases} 1, & V_{ref} < V_s \ \& \ V_{ref} \geq V_L \\ 0, & V_{ref} \geq V_s \ \& \ V_{ref} < V_L \end{cases} \end{aligned} \tag{5}$$

The second way to reset the flip-flop is to compare the reference signal and the integrator's output to increase the controller's reliability. When the error between the reference voltage and the network voltage is a very small number ($\varepsilon = 10^{-5}$), the flip-flop should be reset, which is mentioned in Equation (6).

$$\begin{aligned} FORS_1, S_3, S_5 &= \begin{cases} 1, & V_s - V_{ref} \leq \varepsilon \\ 0, & V_s - V_{ref} > \varepsilon \end{cases} \\ FORS_2, S_4, S_6 &= \begin{cases} 1, & V_s - V_{ref} \leq \varepsilon \\ 0, & V_s - V_{ref} > \varepsilon \end{cases} \end{aligned} \tag{6}$$

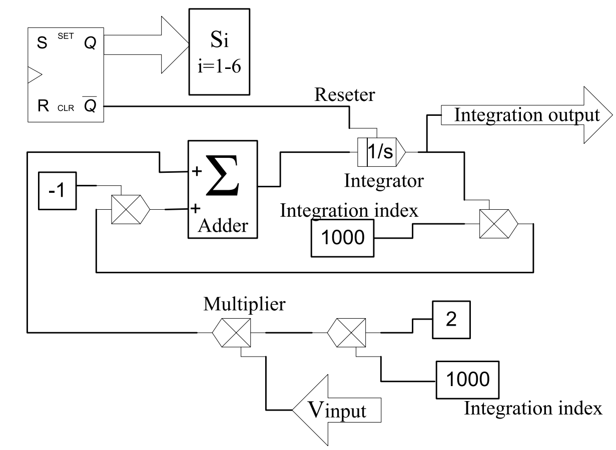

FIGURE 6. Speed increase in the composition of occ.

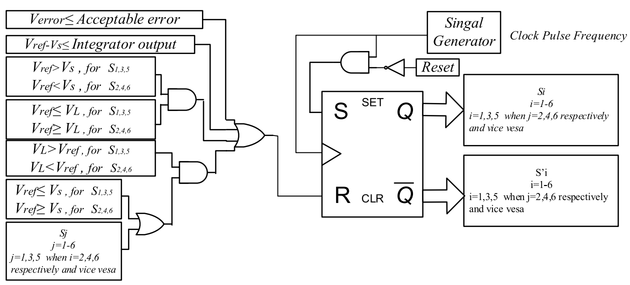

FIGURE 7. RS flip-flop reset paths.

Equation (7) states the third path of resetting the flip-flop, which compares the opposite switch and the desired voltages, load, and network.

$$FORS_1, S_3, S_5 = \begin{cases} 1, & (V_{ref} > V_L or S_2, S_4, S_6) \; \& \; V_s \geq V_{ref} \\ 0, & (V_{ref} < V_L or S_2, S_4, S_6) \; \& \; V_s \leq V_{ref} \end{cases} \quad (7)$$

Finally, Equation (8) describes the fourth path of flip-flop reset when the integral value reaches the reference value.

$$FORS_1, S_3, S_5 = \begin{cases} 1, & e_{ra} \leq e_{a\_r\_p} \\ 0, & e_{ra} > e_{a\_r\_p} \end{cases}$$
$$FORS_2, S_4, S_6 = \begin{cases} 1, & e_{ra} \leq e_{a\_r\_p} \\ 0, & e_{ra} > e_{a\_r\_p} \end{cases} \quad (8)$$

where e_{ra} represents the comparison of the reference voltage and the network voltage, and $e_{a\_r\_p}$ represents the integrator output value.

3) THIRD IMPROVEMENT

Because in this type of control, all maneuvers are on the reset flip-flop, in the *RS* flip-flop, the Reset commands should take precedence over the Set command. Two gates do this command priority. Fig. 7 shows all the paths integrated for the switches and the priority of the Flip Flop Reset command.

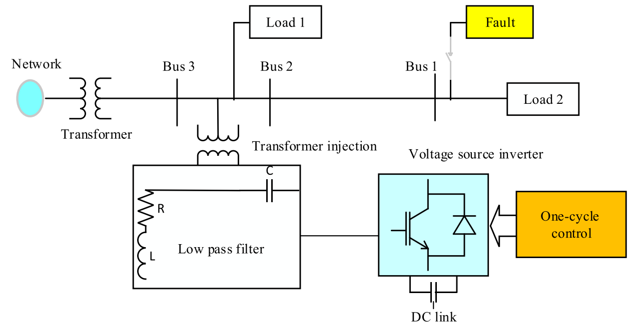

FIGURE 8. Study network and three-level STATCOM.

TABLE 1. System parameters.

Simulation parameters		Value
Source	Amplitude	*1 per unit (20 kV)*
	Frequency	*50 Hz*
Load	Resistance	*70 Ω*
	Inductance	*6.5 mH*
Filter	Capacitor	*180 uF*
	Inductance	*2.75 mH*
	Resistance	*10 Ω*
Injection transformer	Conversion ratio	*1:2*
Switching frequency		*10 kHz*
Pulse clock frequency		*1 MHz*
DC link capacitor capacity		*1100 uF*
Integration coefficient		*1000*

IV. SIMULATION RESULTS

In this section, various case studies are reviewed to demonstrate the effect of the proposed control. It must be noted that the proposed structure in various practical applications such as three phase active filters [19] as well as three phase STATCOM [20] has been implemented and validated previously. The novelty of this paper is to propose an improved one-cycle control algorithm that is implemented on the former tested structures. In order to evaluate the effectiveness of the proposed control algorithm, simulations have been carried out on the available structures. The network understudy and three-level STATCOM are shown in Fig. 8, in which one load is connected to a source via a transmission line, and STATCOM is connected in parallel. The system parameters are presented in Table 1. This paper uses the proposed approach in two case studies for STATCOM. The proposed approach is tested in 4 modes for the first study, and the simulation results are presented. In the case of the second study, to better demonstrate the benefits of the proposed controller, the simulation results of the proposed control and the SPWM method are compared when a fault occurs in the system.

A. *INVESTIGATION OF NETWORK POWER QUALITY PARAMETERS*

The optimum voltages for the load are three pure sinusoidal voltages with a phase difference of 120 ° and a size of 1 per

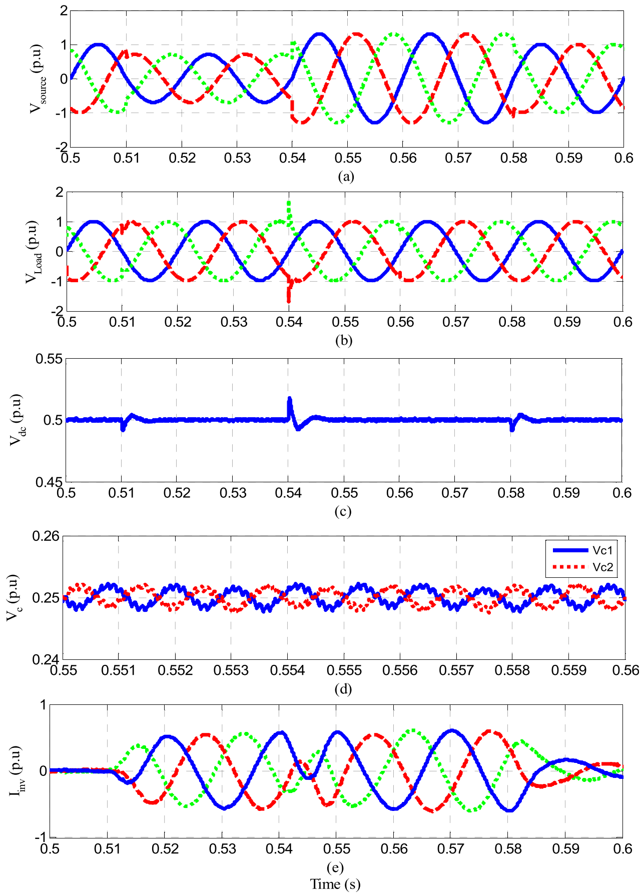

FIGURE 9. **Symmetric voltage sag and voltage swell: (a) network side voltage, (b) load side voltage, (c) dc-link voltage, (d) voltage of each capacitor, and (e) injection current by inverter.**

unit, produced by PLL. The STATCOM compensator can compensate for all network voltage disturbances with the proposed controller. The types of disturbances studied in this section include voltage swell and Voltage sag in the form of symmetric and asymmetric, voltage fluctuations, and voltage harmonics.

1) CASE 1: SYMMETRIC VOLTAGE SWELL AND VOLTAGE SAG OF THE NETWORK VOLTAGE

In this case, the network voltage has the symmetric voltage sag and voltage swell with 30% of the voltage drop from 0.51 to 0.54 and 30% of the voltage swell from 0.54 to 0.57. Fig. 9 shows the simulation results for symmetric Voltage sag and voltage swell. To show the better performance of the proposed method, the voltage difference between the desired voltage, network voltage, and load voltage has been investigated. In Fig. 10, the results of the proposed controller method and the PWM switching method are compared to prove the efficiency of the proposed controller method. STATCOM compensates for symmetrical voltage swell and voltage sag with the PWM switching method, but the steady-state voltage difference is greater than STATCOM with the proposed control.

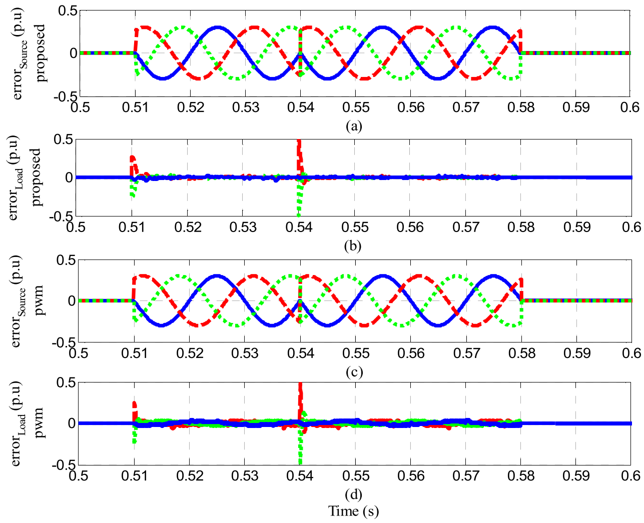

FIGURE 10. **Comparison of the proposed method with the PWM method in the case of symmetric voltage swell and voltage sag: (a) the difference between the voltage on the network side and the desired one when using the proposed controller, (b) load side voltage difference and optimal when using the proposed controller, (c) the difference between the network voltage and the desired one when using the PWM controller, (d) the difference between the load side voltage and the desired one.**

2) CASE 2: ASYMMETRIC VOLTAGE SWELL AND VOLTAGE SAG OF THE NETWORK VOLTAGE

In this section, asymmetric voltage sag and voltage swell in the network voltage are investigated. In this case, in phase a, 15% voltage drop from 0.51 to 0.54 and 35% voltage swell from 0.54 to 0.57, in phase b, 35% voltage drop from 0.51 to There is 0.54 and 25% voltage swell from 0.54 to 0.57 and in phase c, there is 25% voltage sag from 0.51 to 0.54 and 20% voltage swell from 0.54 to 0.57.

Fig. 11 shows the asymmetric voltage sag and voltage swell simulation results. Similar to the first case, to show the proposed method's better performance, the voltage difference between the desired, network, and load voltage has been investigated. In Fig. 12, the results of the proposed controller method and the PWM switching method to prove the efficiency of the proposed controller method have been compared. STATCOM compensates for asymmetric voltage sag and voltage swell with the PWM switching method, but the steady-state voltage difference is greater than STATCOM with the proposed control.

3) CASE 3: NETWORK VOLTAGE FLUCTUATIONS

One of the tasks of the STATCOM compensator is to eliminate voltage fluctuations. In this section, to create a fluctuation in the network voltage, a voltage with an amplitude of 0.4 and a frequency of 4 Hz has been added to the network voltage to confuse the network voltage. This operation has lasted from 0.51 to 0.6 seconds.

Fig. 13 shows the simulation results of network voltage fluctuations. The injection current by STATCOM shows that

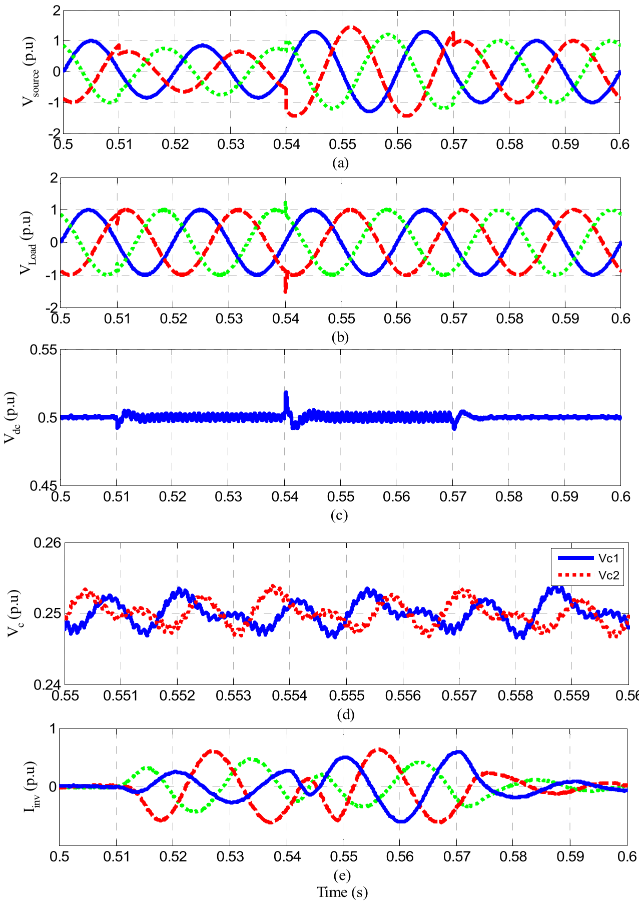

FIGURE 11. Asymmetric voltage sag and voltage swell: (a) network side voltage, (b) load side voltage, (c) dc-link voltage, (d) voltage of each capacitor, (e) injection current by an inverter.

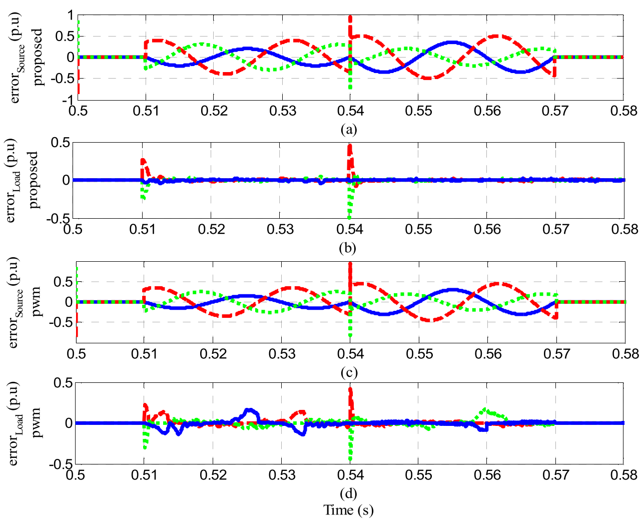

FIGURE 12. Comparison of the proposed method with the PWM method in the case of asymmetric voltage swell and voltage sag: (a) the difference between the voltage on the network side and the desired one when using the proposed controller, (b) load side voltage difference and optimal when using the proposed controller, (c) the difference between the network voltage and the desired one when using the PWM controller, (d) the difference between the load side voltage and the desired one.

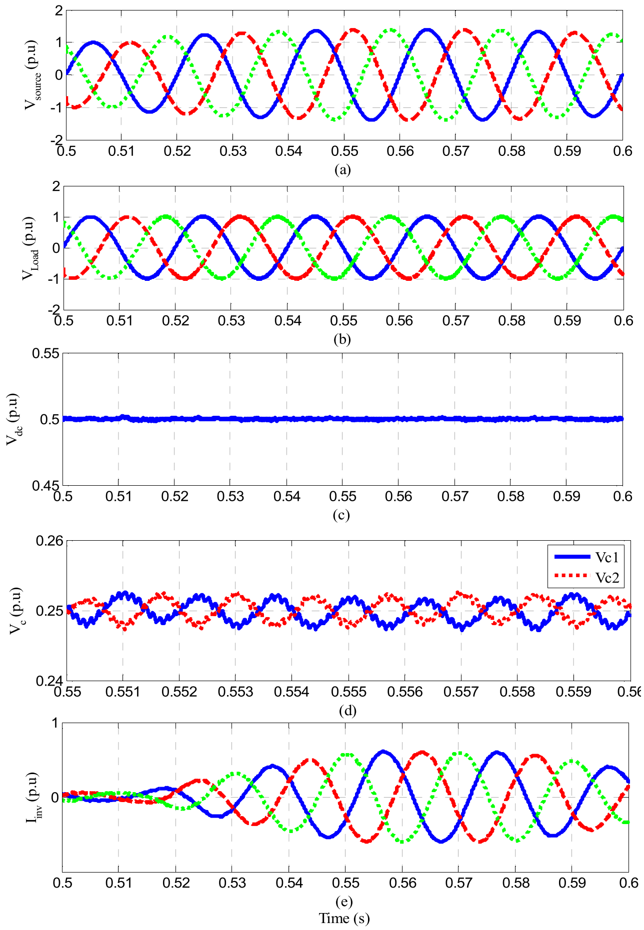

FIGURE 13. Network voltage fluctuations: (a) network side voltage, (b) load side voltage, (c) dc link voltage, (d) voltage of each capacitor, (e) injection current by inverter.

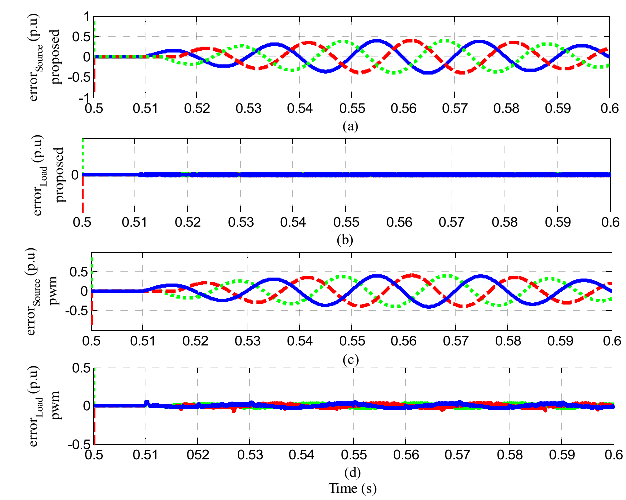

FIGURE 14. Comparison of the proposed method with the PWM method in the case of network voltage fluctuations: (a) the difference between the voltage on the network side and the desired one when using the proposed controller, (b) load side voltage difference and optimal when using the proposed controller, (c) the difference between the network voltage and the desired one when using the PWM controller, (d) the difference between the load side voltage and the desired one.

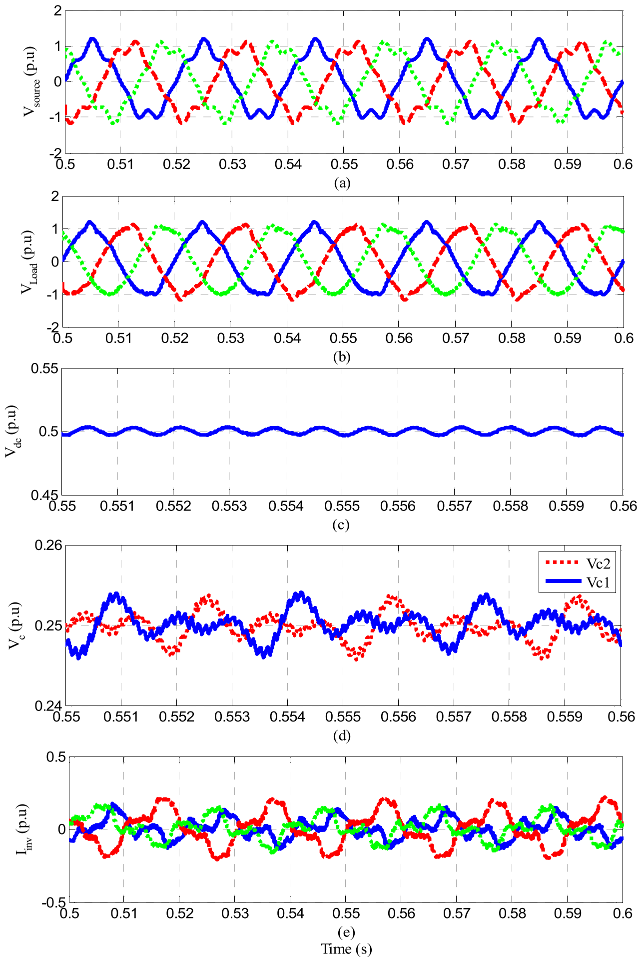

FIGURE 15. Harmonic in network voltage: (a) network side voltage, (b) load side voltage, (c) dc-link voltage, (d) voltage of each capacitor, (e) injection current by inverter.

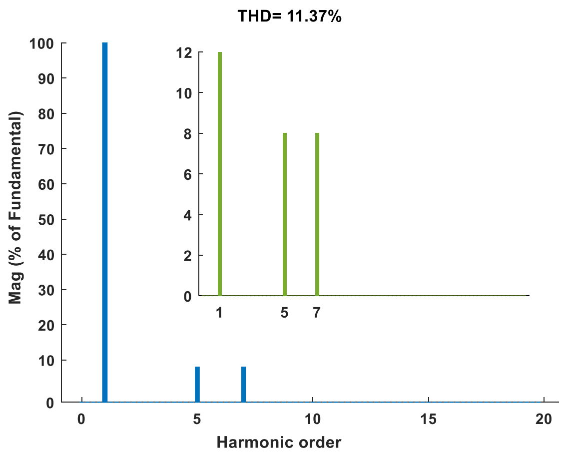

FIGURE 16. Harmonic spectrum of load voltage without STATCOM.

in this case, STATCOM, by injecting the reverse current of the added voltage to the network, was able almost to eliminate the effect of this perturbation on the load voltage and have a sinusoidal voltage on the load side. Similar to the first and second cases, the voltage difference between the desired,

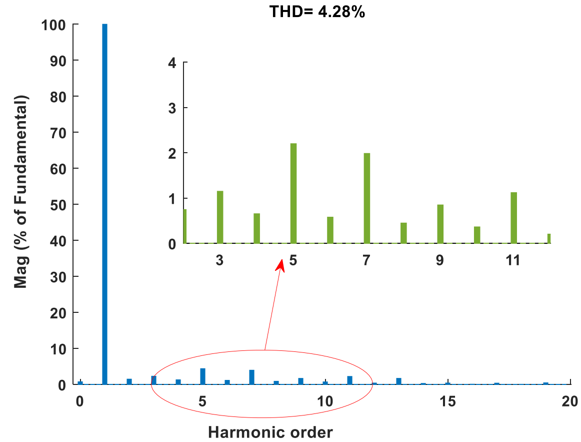

FIGURE 17. Harmonic spectrum of load voltage with STATCOM.

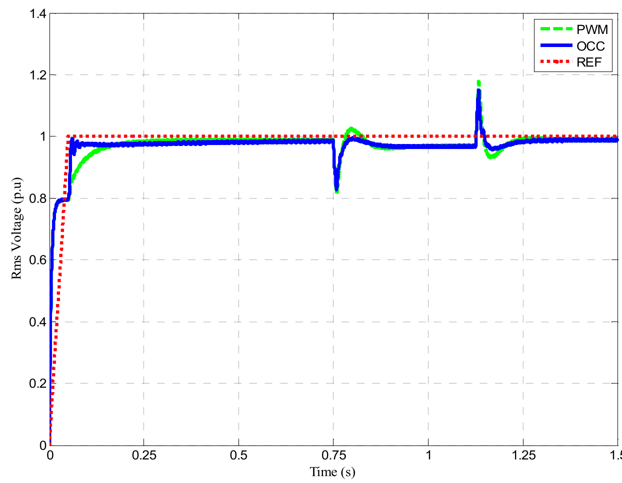

FIGURE 18. Comparative diagram of the effective value of voltage in the presence of both controllers.

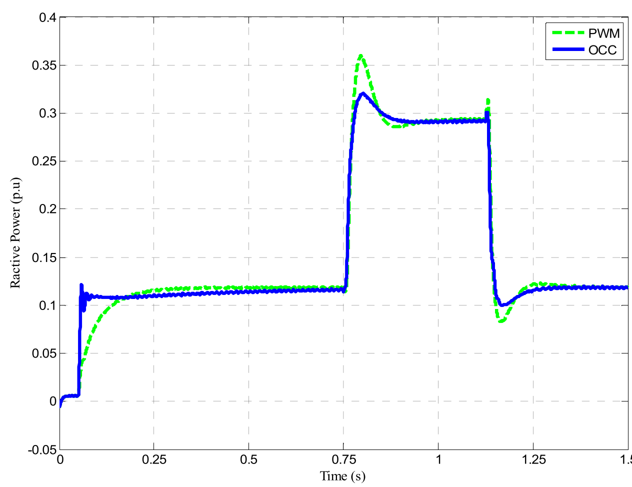

FIGURE 19. Comparative diagram of the reactive power in the presence of both controllers.

network, and load voltage has been investigated to show the proposed method's better performance. In Fig. 14, the results of the proposed controller method and the PWM switching

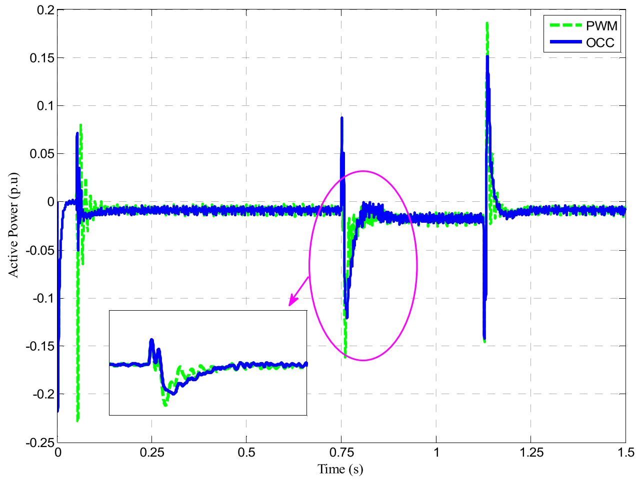

FIGURE 20. Comparative diagram of the active power in the presence of both controllers.

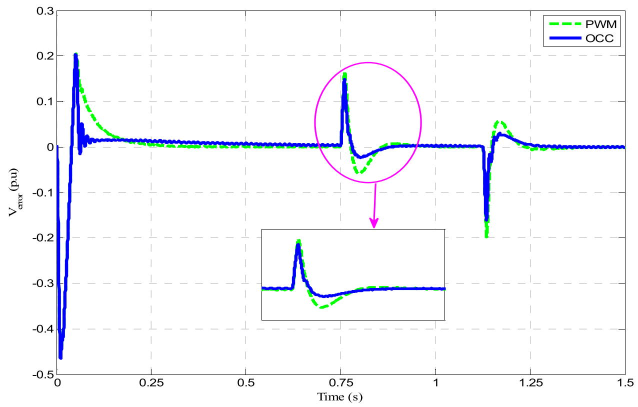

FIGURE 21. Comparative diagram of the effective value of voltage difference in the presence of both controllers.

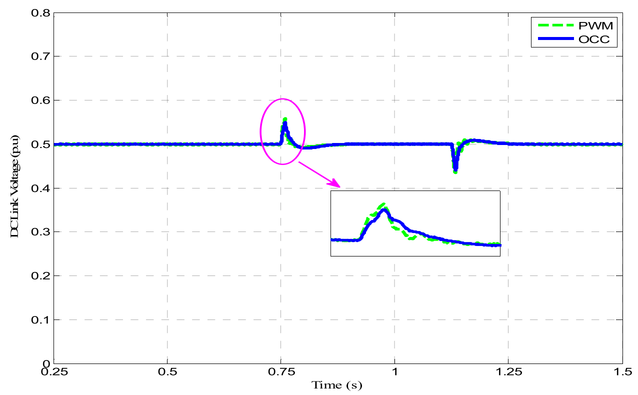

FIGURE 22. Comparative diagram of the dc link voltage value in the presence of both controllers.

method are compared to prove the efficiency of the proposed controller method. STATCOM eliminates network voltage fluctuations with the PWM switching method, but the steady-state voltage difference is greater than STATCOM with the proposed control.

4) CASE 4: HARMONIC IN NETWORK VOLTAGE

Another task of the STATCOM compensator is to eliminate the harmonics in the voltage. In this section, we inject a harmonic with an amplitude of 0.2 and a frequency of 350 Hz into the network voltage, similar to the seventh harmonic injection. This operation lasted from 0 seconds to 0.6 seconds. Fig. 15 shows the results of harmonic simulation at network voltage. Fig. 16 and Fig. 17 show the harmonic spectrum of load voltage without STATCOM and load voltage with STATCOM, respectively. As it turns out, the THD value of the load voltage is lower, and the harmonic value is reduced.

B. COMPARISON OF THE PROPOSED CONTROLLER IN THE EVENT OF A FAULT IN THE DISTRIBUTION SYSTEM

To accurately demonstrate the STATCOM performance improvement with the proposed controller compared to the conventional control, in 1.5 seconds for 0.75, A fault occurred in the distribution system to compare the performance of the proposed one-cycle control method and the conventional PWM method. Fig. 18 shows a comparative diagram of the effective value of voltage in the presence of both controllers. Fig. 19 shows a comparative diagram of the amount of reactive power in the presence of both controllers. Fig. 20 shows a comparative diagram of the amount of active power in the presence of both controllers. Fig. 21 shows a comparative diagram of the effective value of the voltage difference in the presence of both controllers. Fig. 22 shows a comparative diagram of the DC link voltage value in the presence of both controllers.

V. CONCLUSION

In this study, the structure of a three-level inverter is used in STATCOM, which has advantages such as losses and harmonic less than the two-level structure. For the first time, the one-cycle control method in the STATCOM compensator has been used to control the switching. With the presence of the proposed controller, STATCOM was able to successfully correct power quality disturbances such as voltage sag, voltage swell, voltage fluctuations, voltage harmonics, and so on. The advantages of the one-cycle control method over other controllers such as PWM are that it has a response with less error in the steady-state as well as a better response in the dynamic state. For the first time, to increase the response speed of the one-cycle control, a change was made in its structure for use in the STATCOM compensator. Also, to strengthen the one-cycle control as much as possible, paths have been created that have excellent performance in all different modes of turbulence in the network.

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