A COMBINED VECTOR AND DIRECT POWER CONTROL FOR DFIG-BASED WIND TURBINES

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ABSTRACT:

Author has proposed, combination of two methods vector and direct power (CVDPC) is implemented, for the rotor side converter (RSC) of doubly fed induction generators (DFIG). The implemented control system is based on a direct current control by selection of appropriate voltage vectors from predefined switching table. Benefits of vector control (VC) are fast dynamic response, system is robust even there variation in machine parameter, lower mathematical calculation and easy for implementation [1]. If we compare vector control with direct power control (DPC), it offers a advantages like less harmonic distortion and lower ripple count. While carrying out this research author has done simulation based on a Matlab. If we compare with CPDVC with VC and DPC under steady state and transient conditions, and if we take at look simulation results CPDVC method is superior over DPC or VC.

KEYWORDS: Vector control (VC), direct power control (DPC), combined vector and direct power control (CVDPC) and double fed induction generator (DFIGs) etc.

INTRODUCTION:

As many environmental studies, there is exponential growth in usage in electrical power over last decade which may call for energy crisis in near future. Other factor to be consider while, we are using such huge amount of energy is depletion of natural resources. One way to create an right balance is to increase energy production of renewable resources which has great potential worldwide and it may reduce significant load on usage of fossil fuels. If proper utilization of wind energy is been done, then by the end of 2020 world's 10% energy can be fed by wind generation and if forecast goes well, energy produced by wind energy will be 20%-30% by the end of 2040[6]. While implementing a wind generation system, wind turbine plays an important role, wind turbines are classified in two ways based on speed technologies fixed and variable. Variable speed technology has more advantages when compared to fixed type, maximized power capture, decreased in mechanical stresses imposed on the turbine, improvement in power quality, and decreased in acoustical noise. The variable speed technologies can adopt advantages of synchronous generators and doubly fed induction generator (DFIGs) with partial scale converters. Wherever high power applications are involved DFIG is employed, as it possesses advantage of lower cost of converters and lower power losses.

COMBINED VECTOR AND DIRECT POWER CONTROL:

    A. VECTOR CONTROL:

Vector control is the mostly used in the DFIG based WTs. This method is stator active and reactive powers are controlled by using the rotor current vector control. The current vector is decomposed into two components of the stator active and reactive power in synchronous reference frame [2]. By doing this, decoupling between active power controls from the reactive power control happens. The reference for active and reactive power is determined by the maximum power point (MPPT) strategy and the grid requirements. The phase angle of the stator flux space vector is usually used for the controller synchronization. In this paper stator flux oriented frame (SFOF) is used then

overall performance of VC will be highly dependent on the accurate estimation of stator flux position. In order to extract the synchronization signal from stator voltage, phase locked loop (PLL) system is used [7].

$$P_s = \frac{3}{2}\mathrm{Re}(\boldsymbol{V}_s \boldsymbol{i}_s*) = \frac{3}{2}(\boldsymbol{V}_{ds}\boldsymbol{i}_{ds} + \boldsymbol{V}_{qs}\boldsymbol{i}_{qs}) \qquad (1)$$

$$Q_s = \frac{3}{2}\mathrm{Im}(\boldsymbol{V}_s \boldsymbol{i}_s*) = \frac{3}{2}(\boldsymbol{V}_{qs}\boldsymbol{i}_{ds} - \boldsymbol{V}_{ds}\boldsymbol{i}_{qs}). \qquad (2)$$

Using SVOF is used for the synchronization of controllers, V_{qs} gets cancelled and stator active power and reactive power equations are simplified to,

$$P_s = \frac{3}{2}\,\boldsymbol{V}_{ds}\boldsymbol{i}_{ds} \qquad (3)$$

$$Q_s = \frac{-3}{2}\,\boldsymbol{V}_{ds}\boldsymbol{i}_{ds}. \qquad (4)$$

As per stator flux current can be written as

$$\boldsymbol{i}_{ds} = \frac{-L_m}{L_s}\,\boldsymbol{i}_{dr} \qquad (5)$$

$$\boldsymbol{i}_{qs} = -\frac{L_m}{L_s}\left(\boldsymbol{i}_{qr} + \frac{\boldsymbol{V}_{ds}}{\omega_s L_m}\right). \qquad (6)$$

By substituting 5 &6 in 3&4 results in

$$P_s = \frac{-3L_m}{2L_s}\,\boldsymbol{V}_{ds}\boldsymbol{i}_{dr} \qquad (7)$$

$$Q_s = \frac{3L_m}{2L_s}\,\boldsymbol{V}_{ds}\left(\boldsymbol{i}_{qr} + \frac{\boldsymbol{V}_{ds}}{\omega_s L_m}\right). \qquad (8)$$

By looking at above equations we can conclude that stator active and reactive power is controlled through i_{dr} and i_{qr}, respectively.
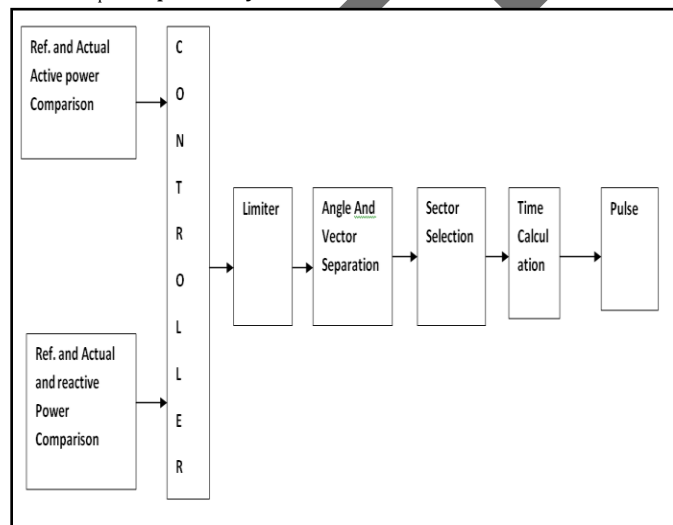

Fig. No.1. Block diagram of RSC based VC

B. DIRECT POWER CONTROL:

In this method, current control loop is deleted and active and reactive power of stator is controlled directly. The DPC can be well demonstrated in following equations.

$$P_s = \frac{-3L_m\omega_s}{2\sigma L_s L_r}|\varphi_s||\varphi_r|\sin\delta \qquad (9)$$

$$Q_s = \frac{3\omega_s}{2\sigma L_s}|\varphi_s|\left[|\varphi_s| - \frac{L_m}{L_r}|\varphi_r|\cos\delta\right]. \qquad (10)$$

By assuming constant magnitude for the stator and rotor flux, the derivative of (9) can be represented approximately as

VECTOR CONTROL:

$$\frac{dP_s}{dt} = \frac{-3L_m\omega_s}{2\sigma L_s L_r}|\varphi_s||\varphi_r|\frac{d\delta}{dt}\cos\delta. \qquad (11)$$

Equation no.11. Shows that there is a relation between active power dynamic and variation of δ .by taking assumption of constant magnitude for the stator flux and δ, the derivative (10) can be re written as

$$\frac{dQ_s}{dt} = \frac{-3L_m\omega_s}{2\sigma L_s L_r}|\varphi_s|\frac{d|\varphi_r|}{dt}\cos\delta. \qquad (12)$$

Equation (11) shows that the stator active power dynamics depends on the variation of . Therefore, the fast active power δ. Voltage equation can be represented and approximated in a short interval of Δt as

$$\frac{d\varphi_r}{dt} = V_r - R_r \boldsymbol{i}_r \approx V_r \Rightarrow \Delta\varphi_r = V_r \cdot \Delta t. \qquad (13)$$

PROPOSED CONTROL SYSTEM:

As described earlier there is relationship between the hysteresis control of the stator active power in DPC and the rotor direct axis current control in VC. It is also demonstrated, hysteresis control of the stator reactive power in DPC closely corresponds to the rotor Quadrature axis current control in VC. Combining the both DPC and VC is possible, and we will get both system advantages in proposed control system architecture.
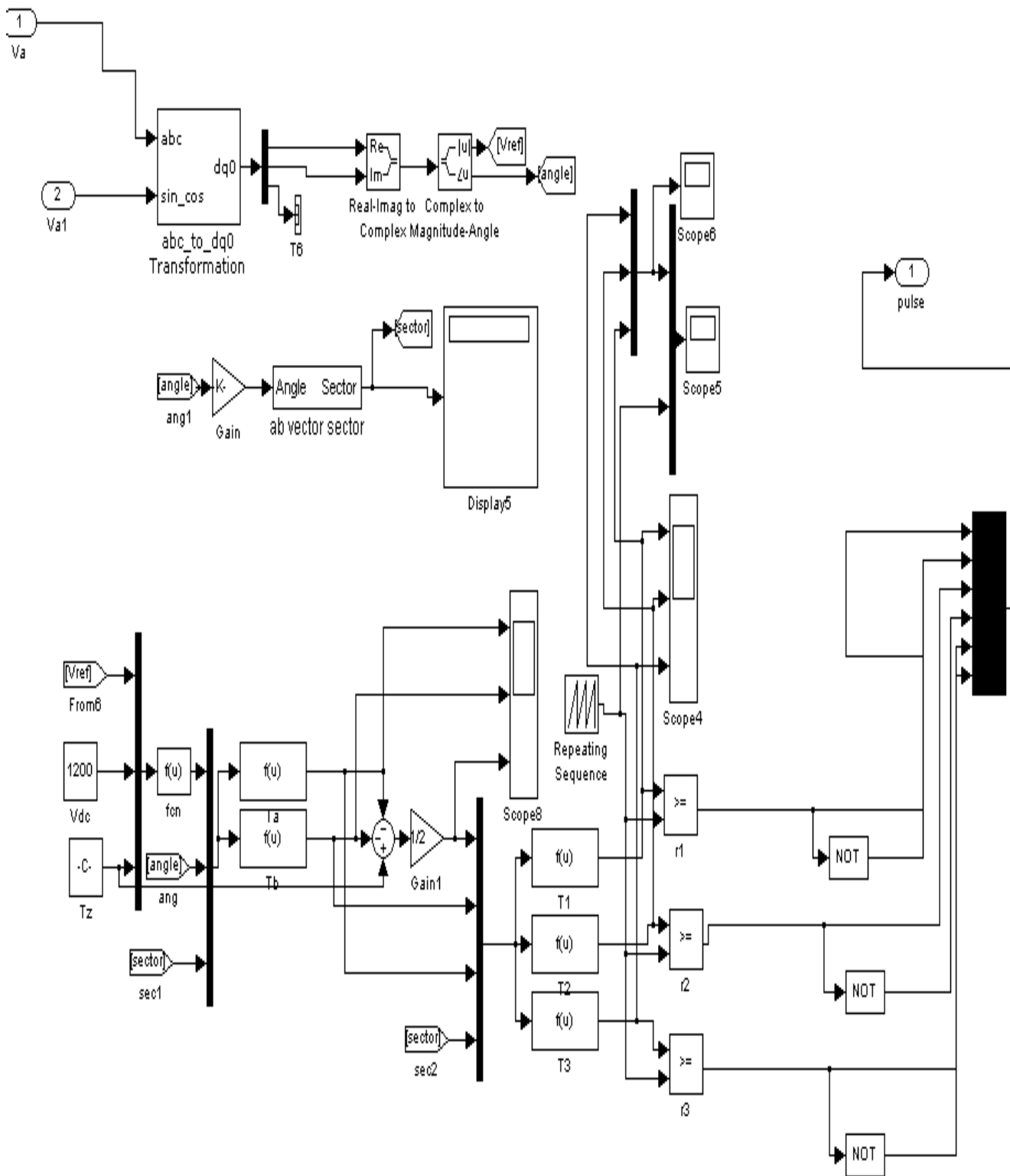
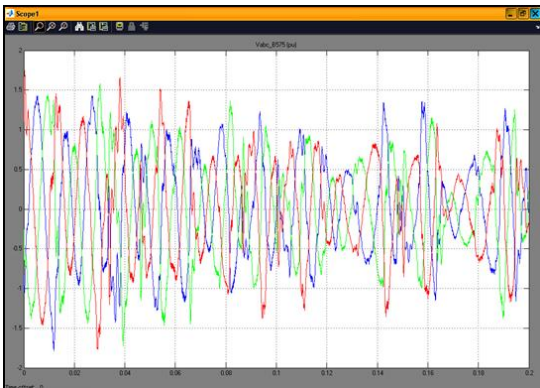Fig. No.2. Implemented Architecture of the Proposed System in MATLAB.
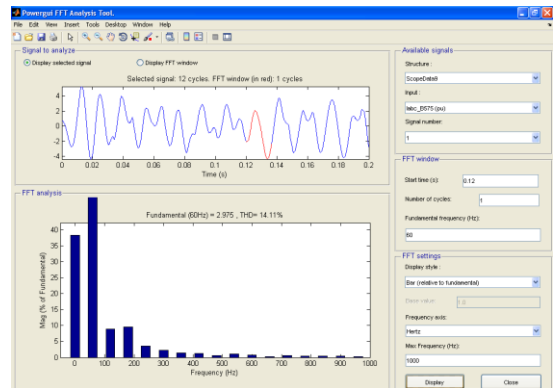
SIMULATION RESULTS:

Fig. No. 3. Wind voltage

Fig. No. 7. Current thd

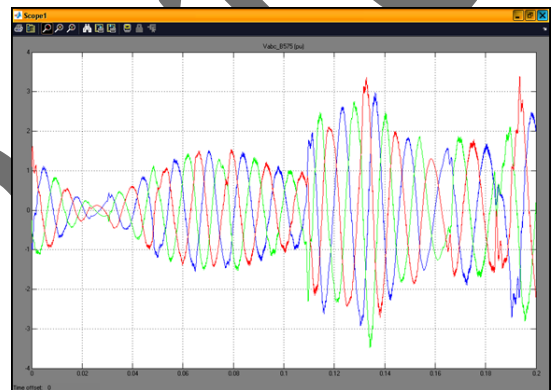### DIRECT POWER CONTROL METHOD:
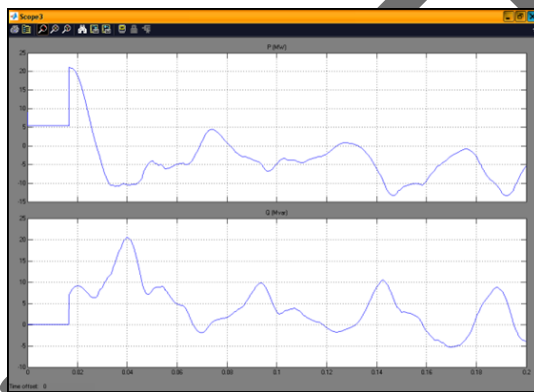

Fig. No.4.Wind current

Fig. No. 8 Wind Voltage

Fig. No.5.Active reactive power

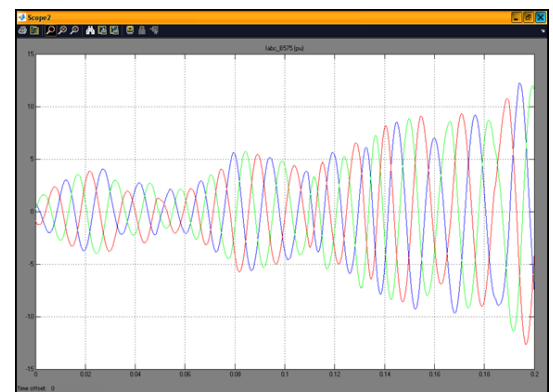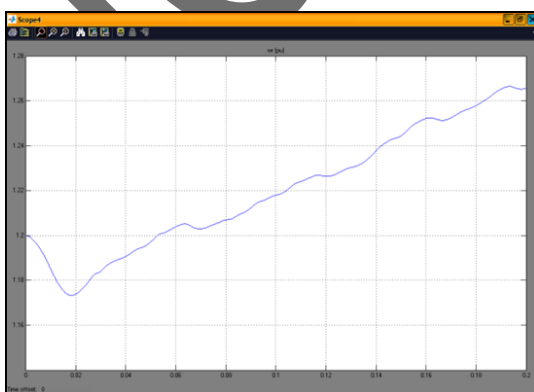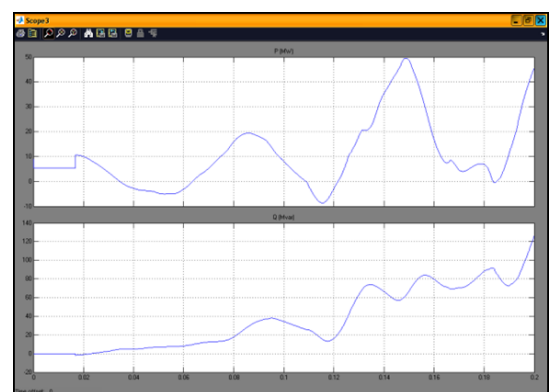Fig. No.9.Wind current

Fig. No.6. Speed

Fig. No.10.Active reactive power
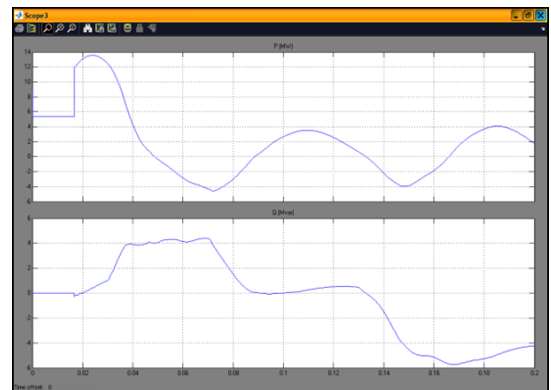
Fig. No.11. Speed

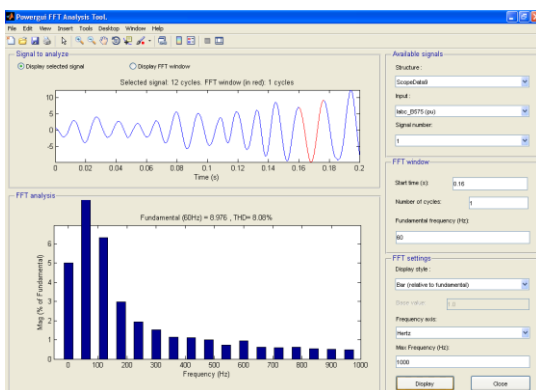Fig. No.15. Active-reactive power
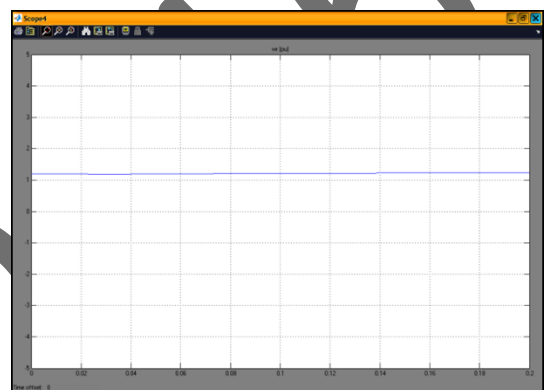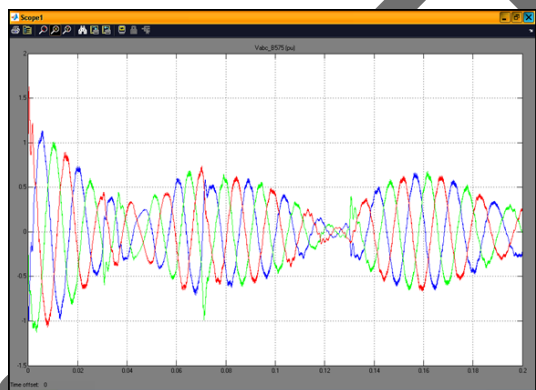

Fig. No.12. Current thd
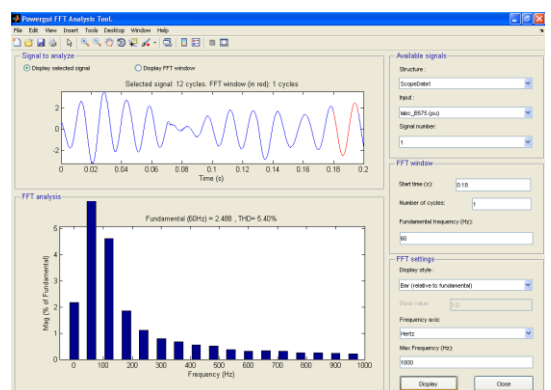

Fig.No.16.Speed

Combined VC and DPC:

Fig. No.13. Wind voltage

Fig. No. 17. Current THD
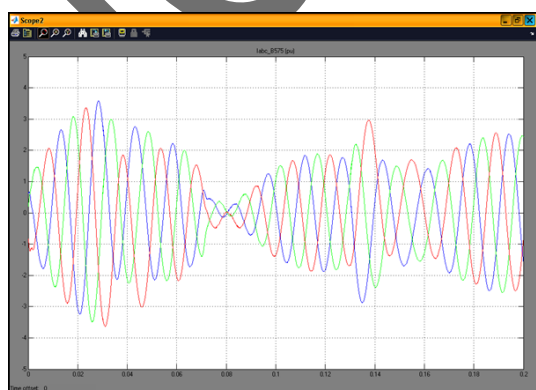
All above results are extensive study of Matlab simulation, based on newly proposed combine vector control and direct power control method (CVDPC). In order to evaluate the implemented method simulation characteristic is divided in two parts steady state and transient. For obtaining best result from CVDPC, controlling gain of PI controller is necessary. To achieve this optimal conventional controller (OCC) type PI controller is used. For comparison the proposed CVDPC with VC in terms of robustness and decoupled performance, changing is suggested a result also shows this condition.

Fig. No. 14. Wind Current

CONCLUSION:

In this paper author has considered of VC and DPC, an implemented combined control scheme termed as combine vector and direct power controller (CVDPC). The implementations of proposed system resulted in increased robustness, lower power ripples, suitable dynamic response and faster response of the system. In steady state condition it is observed that CVDPC has lower power ripples as compared to VC method also ripple is significantly lesser as that of DPC. Moreover, FFT analysis concludes that CVDPC has lower THD as compared to VC and DPC. As a result implemented CVDPC system not only enjoys lower power ripple but it also has high dynamic response.

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