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# Estimation & Mitigation of Power Quality Issues in Transmission Systems with an Advanced Compensation Methods

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**Abstract**

Power quality defines the fitness of electric power to consumer devices i.e. Synchronization of the voltage frequency and phase allow electrical system to function without any significant loss in performance. In distribution system the distribution networks and sensitive industrial loads are suffering from different type of outage and interruption which can lead to loss in production and other measurable and non measurable factor. The factors that are affecting power quality are voltage sag, voltage variation, interruption, swells, brownout, distortions, Harmonic, noise, voltage spikes, voltage flicker etc. This causes some deviations in the power when compared with the normal standards. The above problems may overcome by using compensation devices (custom power devices) either compensate load i.e. correct its power factor, unbalance etc. or improve the quality of the supply voltage. In this project we are estimating all the power quality issues by different methods (FFT analysis Wavelets) & mitigating the issues by Fuzzy logic controller (FLC) DVR , SVPWM & multi level compensators, multi level DVR, statcom are done by matlab simulation.

**Index Terms:** Multi Level, Dynamic Voltage Restorer, FLC, SVPWM, Wavelets, Sag, Swell

## I. INTRODUCTION

Now a days due to increased power quality problems by using of switch off/on introduction loads, nonlinear load and induction motor etc in domestic and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network Faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation. To meet power quality to the standard limits need some sort of compensation. In few years back to mitigate the power quality problems in distribution system by using passive filters like capacitor banks. Now these research going very fast to mitigate the power quality problems with help of power conditioning devices. The power conditioning devices are dynamic voltage restorer (DVR), static compensator (STATCOM), multi level compensators and SVPWM based compensators.

## II. MULTI-LEVEL INVERTER

Numerous of the industrial and commercial applications require medium and high power equipment in the range of megawatt (MW). Used for all such applications a single switch shouldn't be connected and so a family of switches has to be connected. The introduction of multilevel inverter which can be practically efficiently is high as well as for medium power applications. These inverters are made up of an arrangement of capacitors voltage sources, power semiconductor from which they tend to generate stepped output voltage waveforms. ϖ Topologies of Multilevel Inverter In the modern era many different multilevel inverter topologies were proposed. There are mainly three different basic topologies which remain the basis for many of the modern ones proposed.

They are

[1] Diode Clamped inverter multilevel

[2] Flying Capacitor or Capacitor Clamped Inverter

[3] Cascaded H-bridge Multilevel Inverter

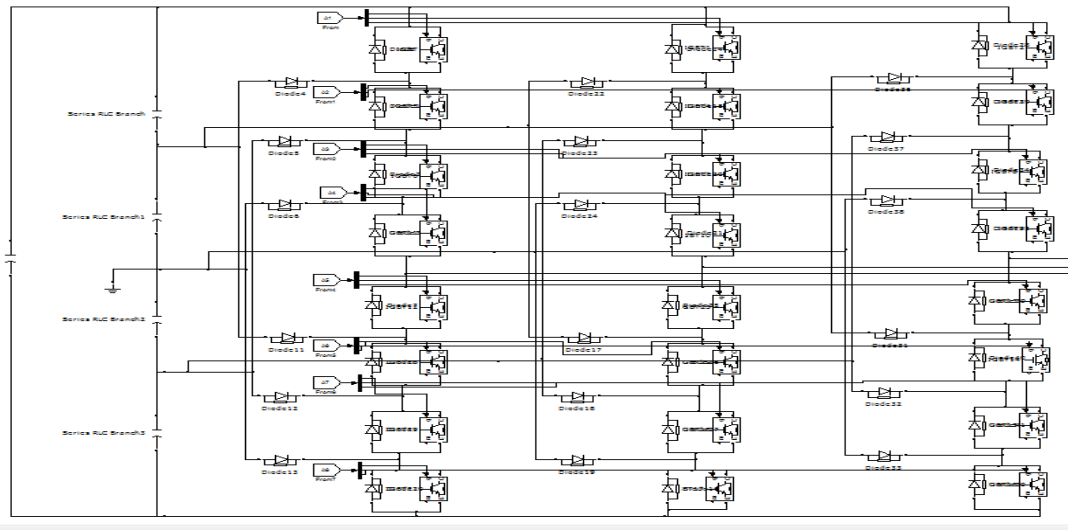


**Fig. 1:** Diode Clamped Multilevel Inverter

Diode Clamped Multilevel Inverter Now for this inverter topology the clamping purpose is served by using a diode as in fig.2. The output required set of steps voltage waveform. Figure shows linking series of capacitors in the 3 level diode clamped inverter. Multiple voltages will be provided for the M level inverter each of the capacitor has a voltage of VDC/m-1. As a result of capacitor voltage balancing issues, the diode-clamped inverter implementation has been mostly limited to the three-level. In this topology, maximum output voltage which can be obtained is half of the input DC voltage. This has been the main drawback for this topology. But this problem can be overcome by increasing the number of switches, capacitors, diodes. Three level inverters of this type are extensively being used in industries these days. Applications

- They are used for Harmonic compensation purpose
- They are used for motor drives with variable speed.
- High voltage DC, AC transmission lines use t

## III. SPACE VECTOR PULSE WIDTH MODULATION

A different approach to SPWM is based on the space vector representation of voltages in the d, q plane. The d, q components are found by Park transform, where the total power, as well as the impedance, remains unchanged.

Fig: space vector  shows 8 space vectors in according to 8 switching positions of inverter, V* is the phase-to-center voltage which is obtained by proper selection of adjacent vectors V1 and V2.

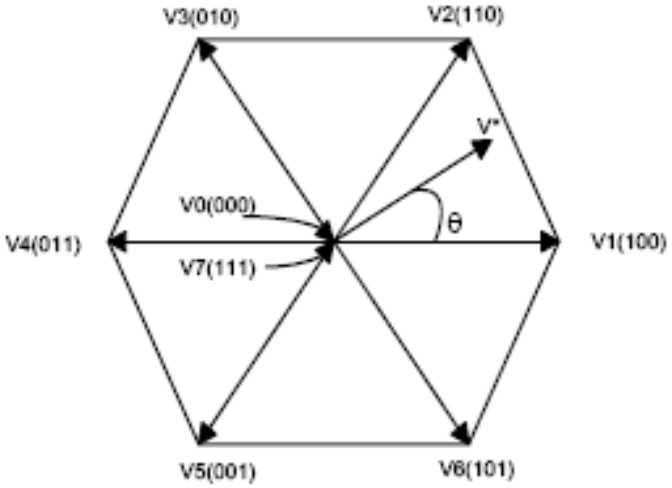



**Fig 2:** Inverter output voltage space vector

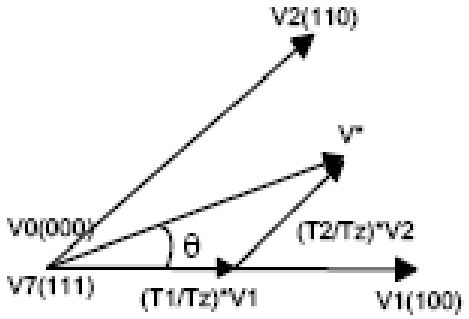



**Fig 3:** Determination of Switching times

The reference space vector V* is given by Equation (1), where T1, T2 are the intervals of application of vector V1 and V2 respectively, and zero vectors V0 and V7 are selected for T0.

$$V^* Tz = V1 *T1 + V2 *T2 + V0 *(T0/2) + V7 *(T0/2)…….(4)$$

SPACE VECTOR PULSE WIDTH MODULATION

Fig. below shows that the inverter switching state for the period T1 for vector V1 and for vector V2, resulting switching patterns of each phase of inverter are shown in Fig. pulse pattern of space vector PWM.

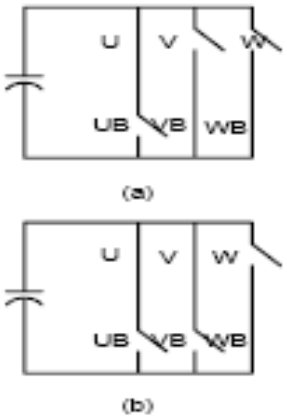



**Fig 4:** Inverter switching state for (a)V1, (b) V2

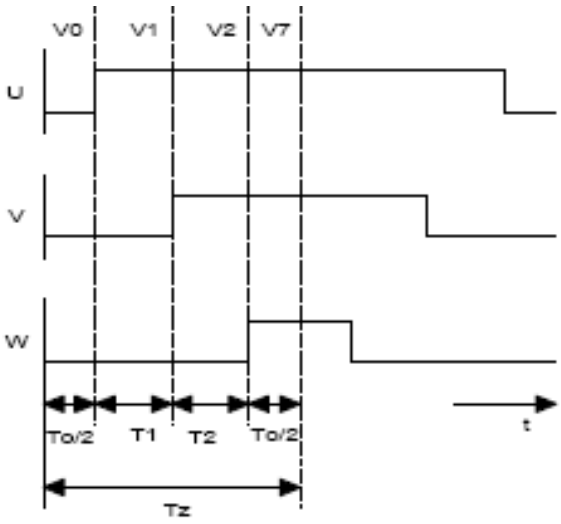
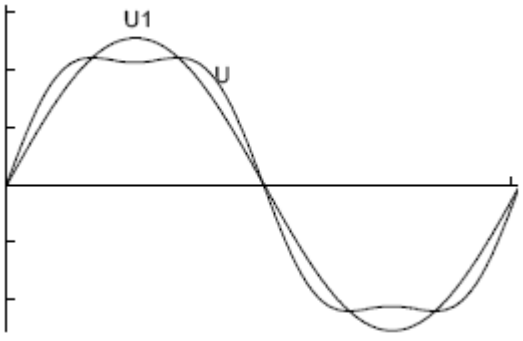



**Fig 5:** Pulse pattern of Space vector PWM



## IV CONTROL SCHEME OF DVR

A DVR is connected in series with the linear load to compensate for the harmonics and unbalance in the source voltages and improve the power factor on the source side (at PCC).[7]The major objective of the control strategy is to ensure that the load bus voltages remain balanced and sinusoidal (positive sequence). Since the load is assumed to be balanced and linear, the load currents will also remain balanced (positive sequence) and sinusoidal. An additional objective is to ensure that the source current remains in phase with the fundamental frequency component of the PCC voltage. This requires that the reactive power of the load is met by the DVR. It is also possible to arrange that DVR supplies a specified fraction of the reactive power required by the load such as microprocessors.

### B. Calculation of DVR Voltage Injection

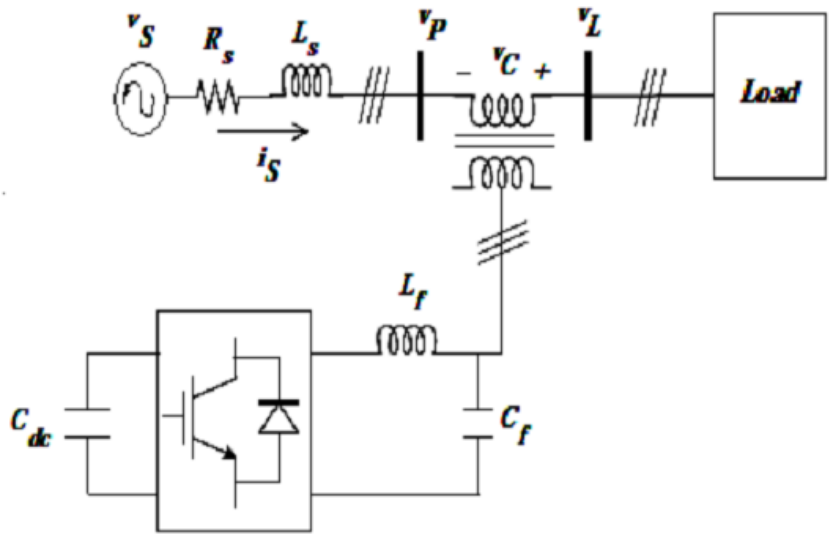



**Fig.6:** DVR series connected topology.

When voltage drop occurred at load, DVR will inject a series voltage through transformer so that load voltage can be maintained at nominal value as shown in Fig.6. Thus, the DVR voltage and Load current

$$V_{DVR} = V_L + Z_{th}I_L - V_{th} \quad (1)$$

$$I_L = \left[\frac{P_{L+jQ_L}}{V_L}\right] \quad (2)$$

If VL is considered as a reference;

$$V_{DVR}\angle\alpha = V_L\angle 0^0 + Z_{th}I_L\angle(\beta+\theta) - V_{th}\angle\delta \quad (3)$$

Here α, β, and δ are the angle of $V_{DVR}$, $V_{th}$, and $Z_{th}$ respectively and θ is the load power factor angle with

$$\theta = \tan^{-1}\left(\frac{Q_L}{P_L}\right) \quad (4)$$

Thus, the power injection of the DVR can be written as

$$S_{DVR} = V_{DVR}I_L \quad (5)$$

**Adaptive Fuzzy Dividing Frequency-Control Method**

The conventional linear feedback controller (PI controller, state feedback control, etc.) is utilized to improve the dynamic response and/or to increase the stability margin of the closed loop system. However, these controllers may present a poor steady-state error for the harmonic reference signal. An adaptive fuzzy dividing frequency control method is presented in Fig., which consists of two control units: 1) a generalized integrator control unit and 2) a fuzzy adjustor unit. The generalized integrator, which can ignore the influence of magnitude and phase, is used for dividing frequency integral control, while fuzzy arithmetic is used to timely adjust the PI coefficients.

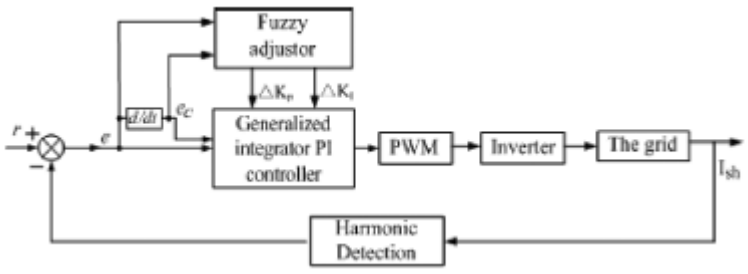



**Fig.7:** Configuration of the adaptive fuzzy dividing frequency controller

Since the purpose of the control scheme is to receive a minimum steady-state error, the harmonic reference signal r is set to zero. First, supply harmonic current is

detected. Then, the expectation control signal of the inverter is revealed by the adaptive fuzzy dividing frequency controller. The stability of the system is achieved by a proportional controller, and the perfect dynamic state is received by the generalized integral controller. The fuzzy adjustor is set to adjust the parameters of proportional control and generalized integral control. Therefore, the proposed harmonic current tracking controller can decrease the tracking error of the harmonic compensation current, and have better dynamic response and robustness.

B. Fuzzy Adjustor

The fuzzy adjustor is used to adjust the parameters of proportional control gain $K_P$ and integral control gain $K_I$, based on the error e and the change of error $e_c$

$$\begin{cases} K_P = K_P^* + \Delta K_P \\ K_I = K_I^* + \Delta K_I \end{cases}$$

Where $K_P^*$ and $K_I^*$ are reference values of the fuzzy-generalized integrator PI controller. In this paper, $K_P^*$ and $K_I^*$ are calculated offline based on the Ziegler–Nichols method. In a fuzzy-logic controller, the control action is determined from the evaluation of a set of simple linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. A block diagram fuzzy-logic adjustor is shown in Fig.

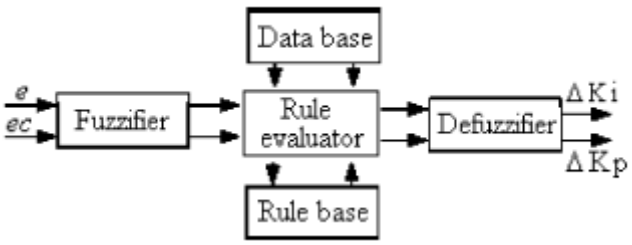



**Fig. 8:** Block diagram of the fuzzy adjustor unit

In this way, system stability and a fast dynamic response with small overshoot can be achieved with proper handing of the fuzzy-logic adjustor. Fuzzification converts crisp data into fuzzy sets, making it comfortable with the fuzzy set representation of the state variable in the rule. In the fuzzification process, normalization by reforming a scale transformation is needed at first, which maps the physical values of the state variable into a normalized universe of discourse.

The error e and change of error $e_c$ are used as numerical variables from the real system. To convert these numerical variables into linguistic variables, the following

seven fuzzy levels or sets are chosen as [17]: negative big (NB), negative medium (NM), negative small (NS), zero (ZE), and positive small (PS), positive medium (PM), and positive big (PB). To ensure the sensitivity and robustness of the controller, the membership function of the fuzzy sets for $e(k)$, $e_c(k)$, $\Delta K_P$, and $\Delta K_I$ in this paper are acquired from the ranges of $e$, $e_c$, $\Delta K_P$, and $\Delta K_I$, which are obtained from project and experience. And the membership functions are shown in Fig., respectively.

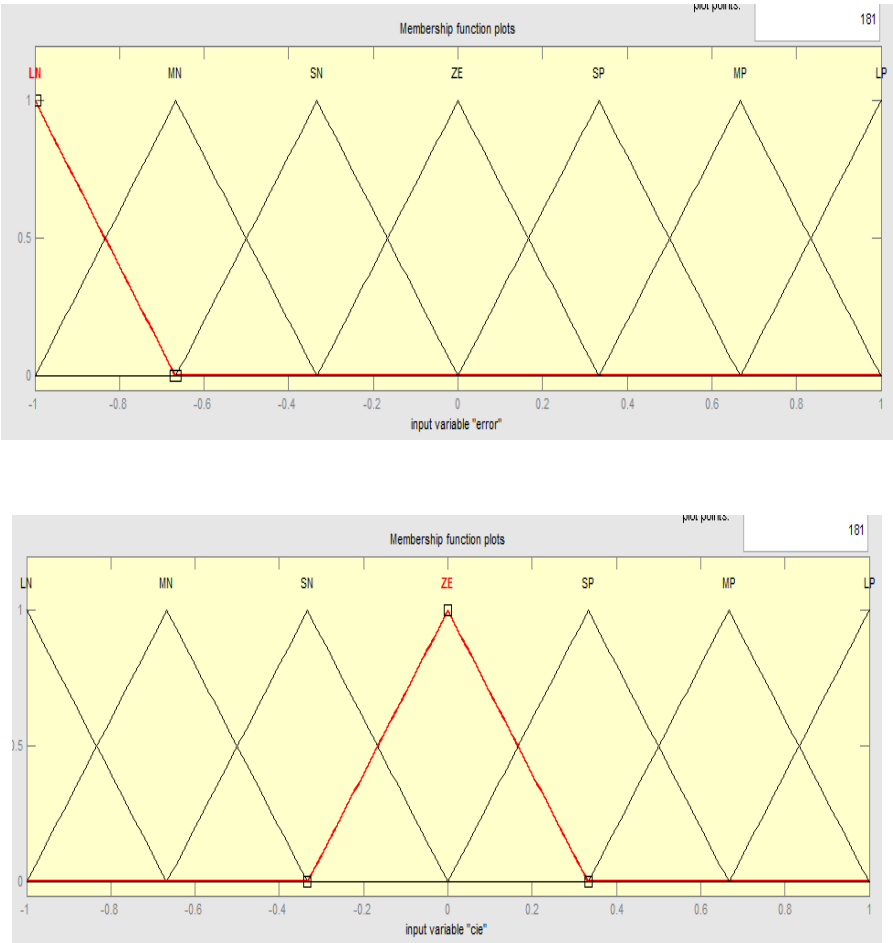



**Fig.9:** Membership functions of the fuzzy variable. (a) Membership function of $e(k)$ and $e_c(k)$

(b) Membership function of $\Delta K_P$ and $\Delta K_I$.

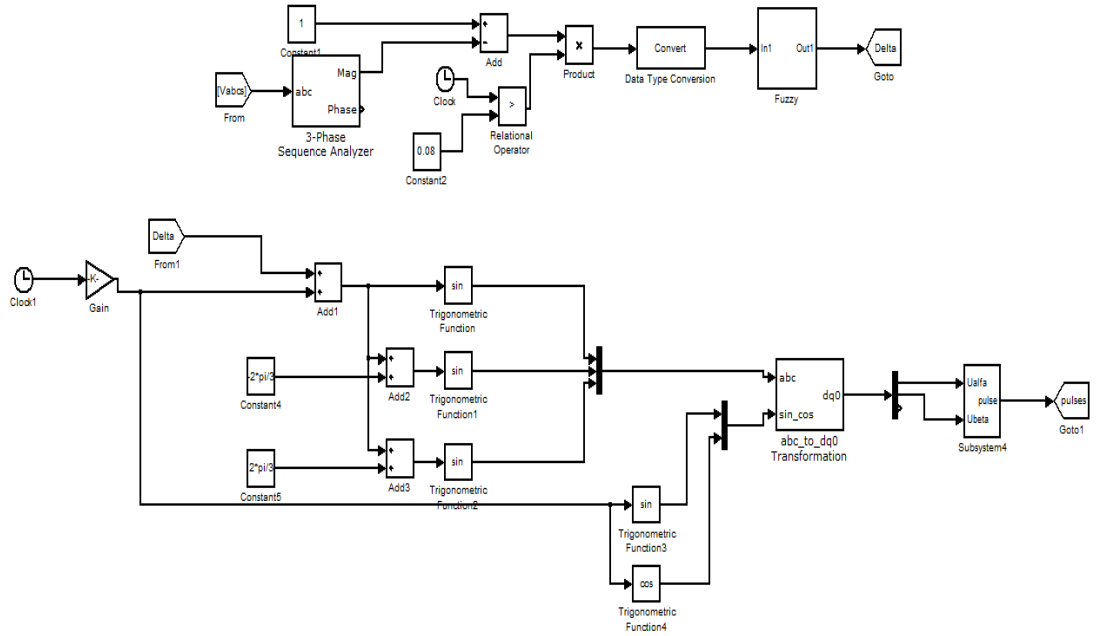



**Fig.10:** Control structure

## V. SIMULATION MODEL & RESULTS

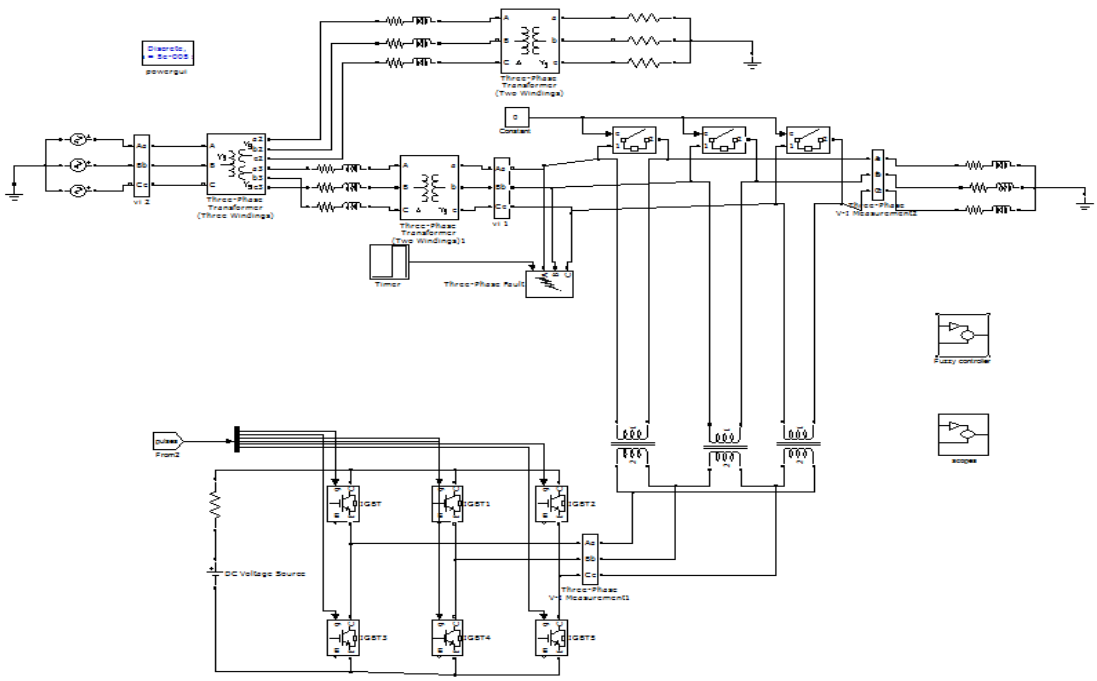


**Fig.11:** Simulink diagram of closed loop system for voltage sag and swell

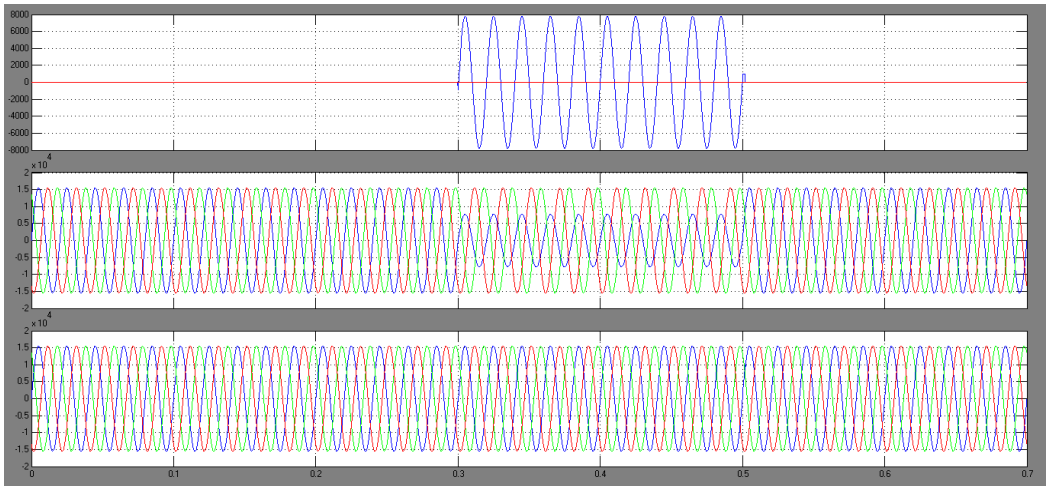


**Fig.12:** source voltage, voltage sag, compensated output voltage

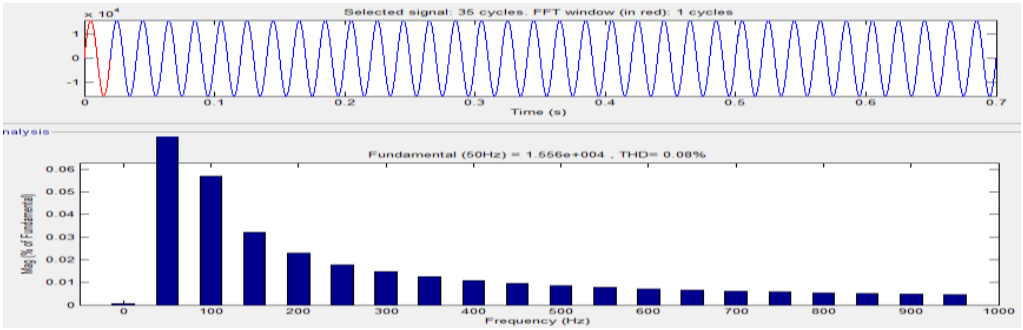



**Fig.13:** FFT analysis of voltage sag of DVR

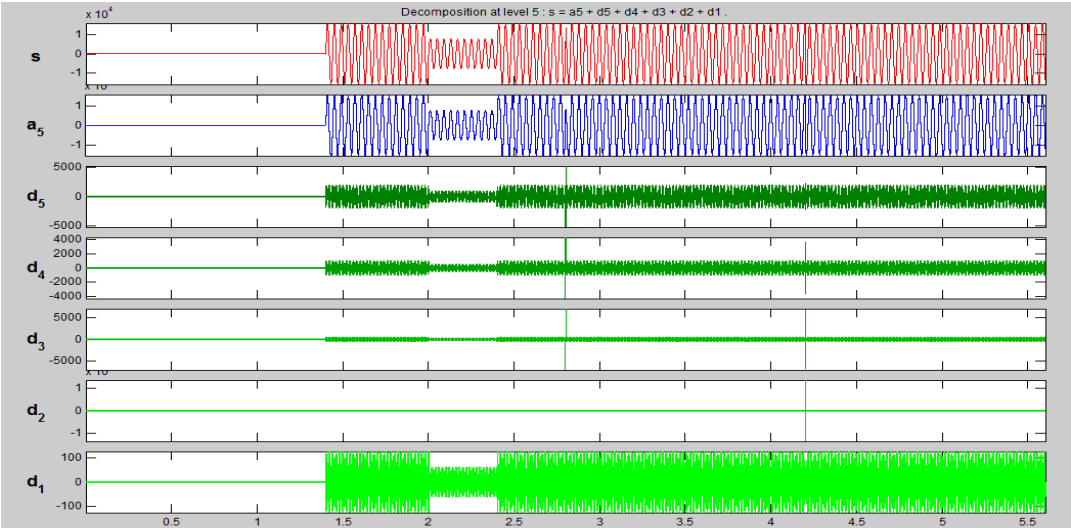



**Fig.14:** wavelet analysis of sag

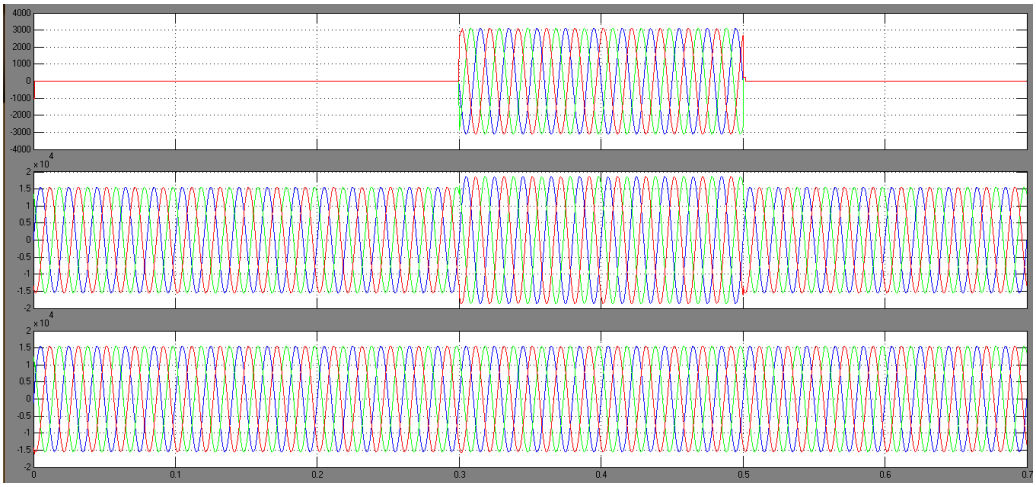


**Fig.15:** source voltage, voltage swell, compensated output voltage

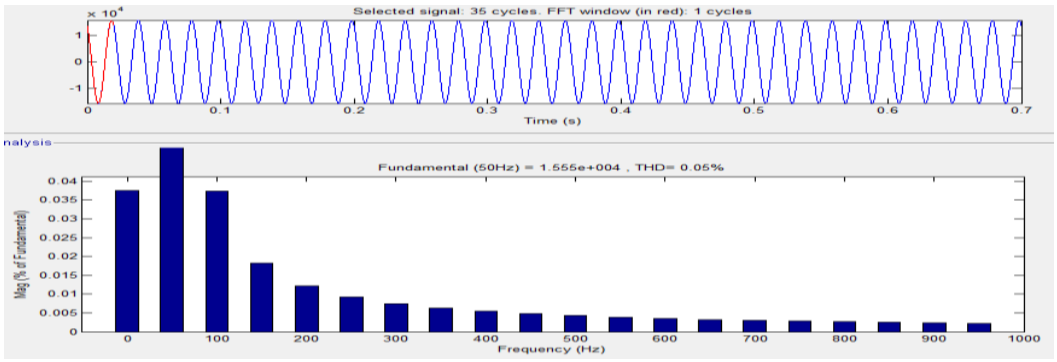



**Fig.16:** THD analysis of voltage swell of DVR

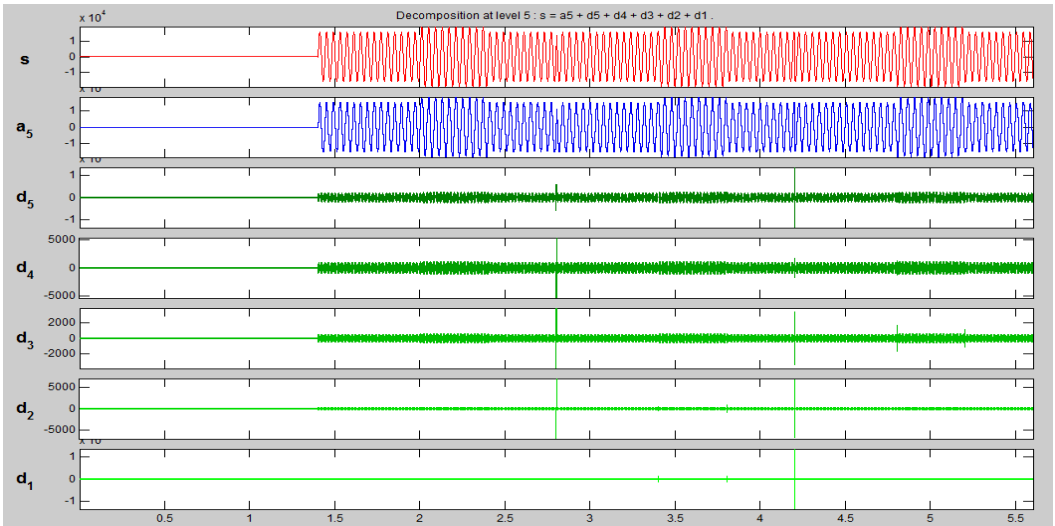



**Fig.17:** wavelet analysis of swell

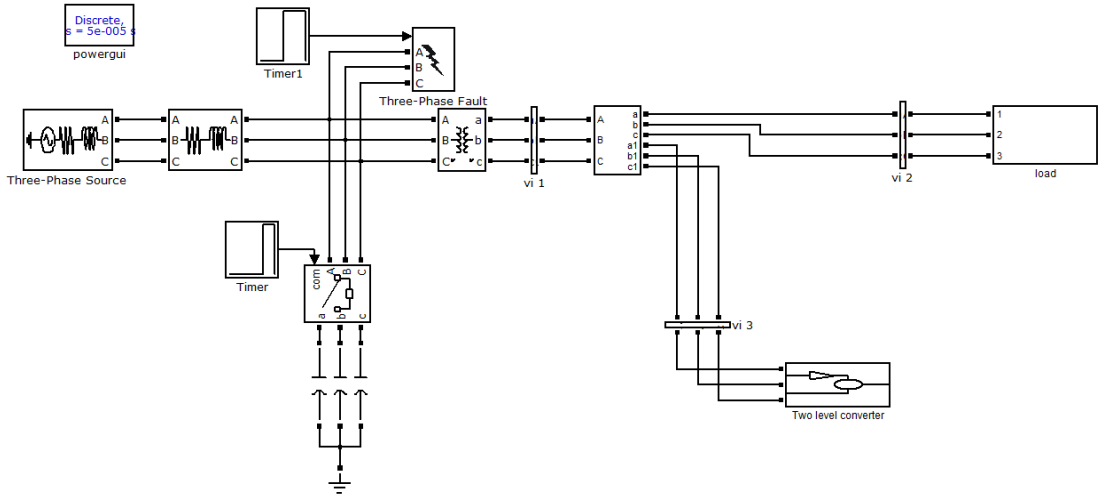



**Fig. 18:** matlab simulation ckt of multi level DVR

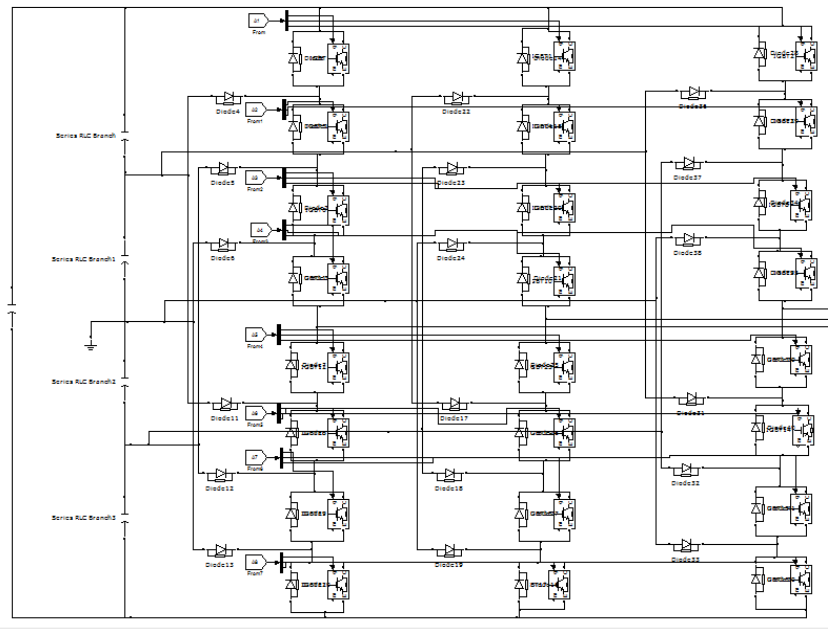
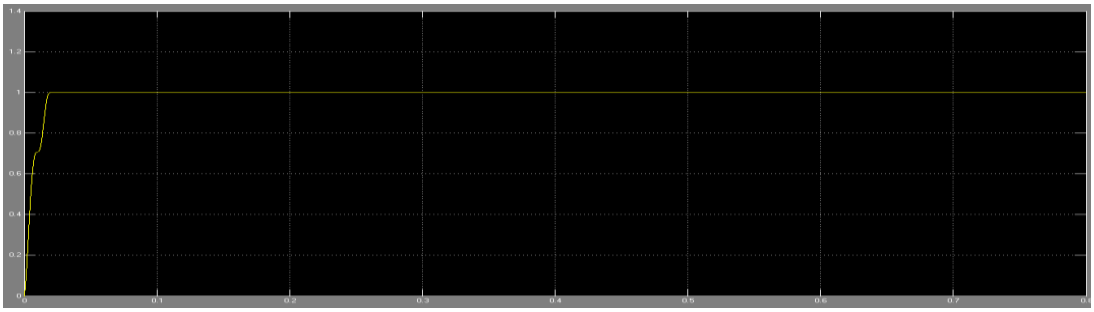


**Fig 19:** five level converter based DVR system



| Device connected | Power facto | T.H.D | Compensated voltage | Compensated current |
|---|---|---|---|---|
| Without compensator | 0.62 | 25.5 | 0v | 0v |
| With 3 level DVR | 0.72 | 6.5 | 464v | 2.3A |
| With 5 level DVR | 0.74 | 4.6 | 764v | 2.3A |
| With 3 level STATCOM | 0.72 | 10.9 | 264v | 7.2A |
| With 5 level STATCOM | 0.76 | 6.1 | 264v | 10.3A |
| SVPWM converter | 0.89 | 1.2 | 874V | 15.7A |
| Fuzzy DVR | 0.91 | 0.12 | 890V | 16.7A |

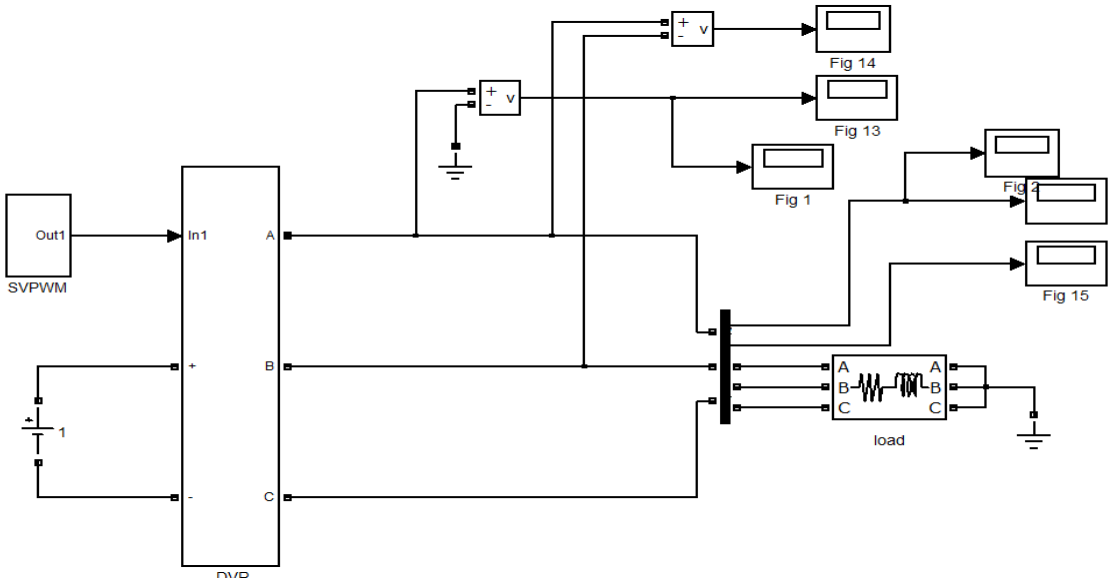



**Fig 20:** multi level SVPWM based Compensator

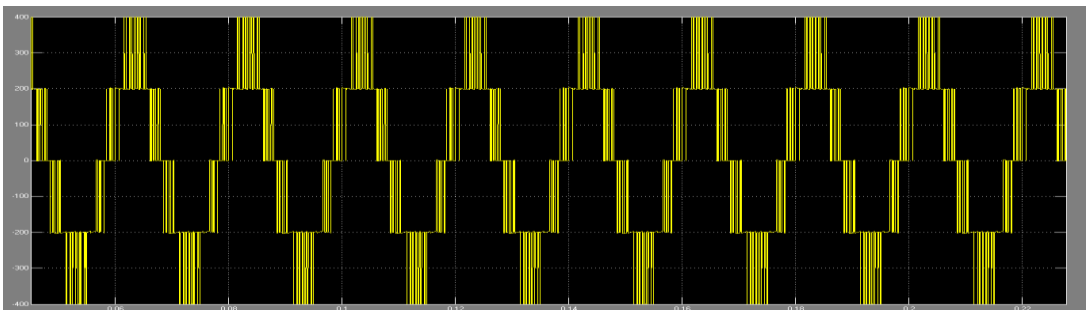


**Fig 21:** multi level voltages

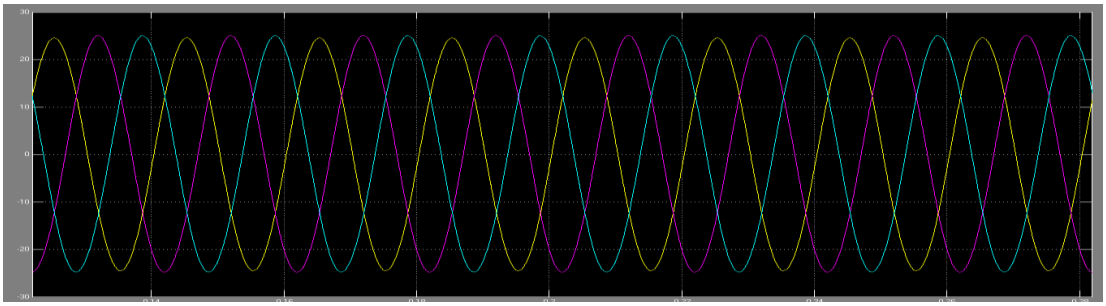


**Fig 22:** current at the load

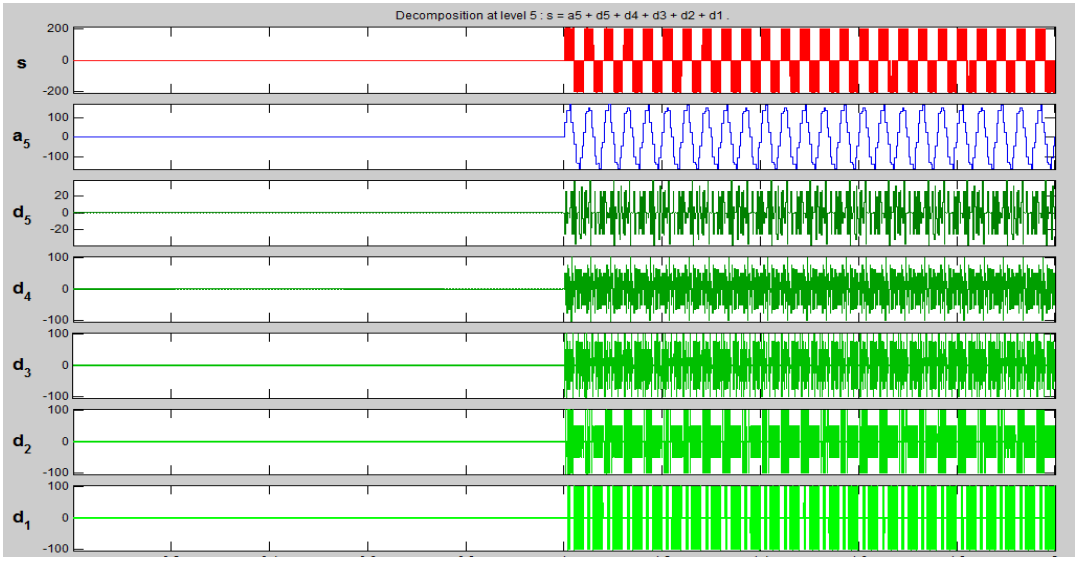



**Fig 23:** analysis by wavelets

## CONCLUSION

In this paper an overview of multi level DVR is presented. DVR is an effective custom power device for voltage sags and swells mitigation. The impact of voltage sags on sensitive equipment is severe. Therefore, DVR is considered to be an efficient solution due to its relatively low cost and small size, also it has a fast dynamic response. In this paper, a new configuration has been proposed which not only improves the compensation capacity of the IDVR at high power factors, but also increases the performance of the compensator to mitigate deep sags at fairly moderate power factors. These advantages were achieved by decreasing the load power factor during the sag condition. In this technique, the source voltages are sensed continuously and when the voltage sag is detected, the shunt reactance's are switched into the circuit and decrease the load power factors to improve IDVR performance. Finally, the simulation and practical results on the CHB-based IDVR confirmed the

effectiveness of the proposed configuration and control scheme. The simulation results show clearly the performance of a multi level DVR in mitigating voltage sags and swells. The multi level DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value.

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