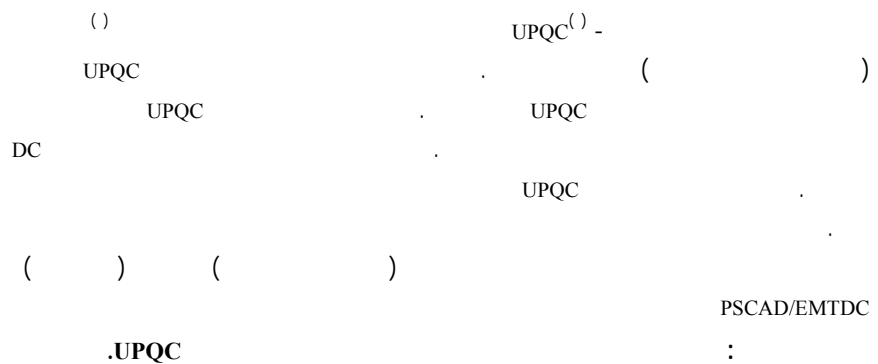


UPQC



UPQC Performance Improvement Using Combination of Instantaneous Power Balance and Synchronous Reference Frame Methods

R. Noroozian, G. B. Gharehpetian, M. Abedi and S.H. Fathi
Faculty of Electrical Engineering, Amirkabir University of
Technology, Tehran, Iran

Abstract

UPQC (Unified Power Quality Conditioner) is an advanced custom power device, which can be used in the case that the load is non-linear and the system supply voltage is distorted simultaneously. It consists of a series and shunt Voltage Source Converter (VSC) with a common DC link. The shunt VSC is mainly intended for conditioning the current flowing from a load into the network and series VSC is mainly used to protect sensitive loads against power quality problems caused by disturbances in supply system. In this paper, a new control strategy for the UPQC is proposed. This control strategy is based on two different methods; the Instantaneous Power Balance Method and Synchronous Reference Frame Method. These two methods have been used earlier independently. Each of them has merits and demerits. To overcome their drawbacks, the instantaneous power balance method has been applied to the shunt VSC and synchronous reference frame method has been applied to the series VSC of UPQC. The simulation results of UPQC in a typical distribution system, carried out by PSCAD/EMTDC, verify the performance improvement of UPQC. It is shown that using this combination of control strategy, the power quality problems in distribution systems can be solved easily.

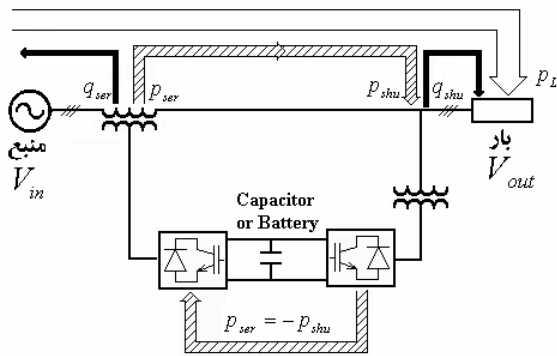
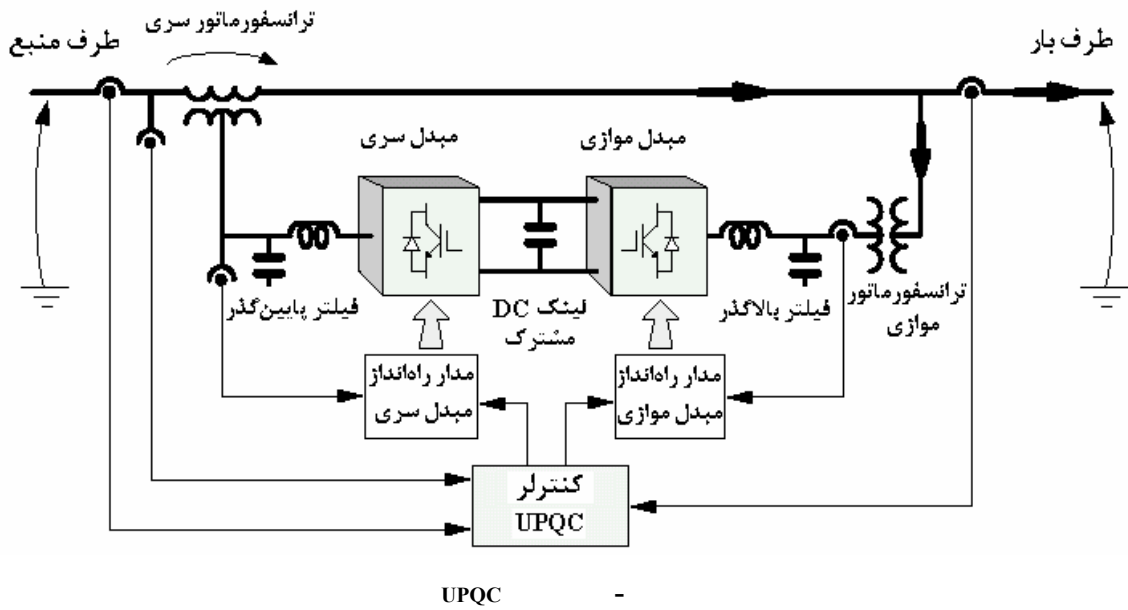
Key words: UPQC, Custom power, Power quality, EMTDC and control strategy.

1- Unified Power Quality Conditioner
2- Custom Power

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UPQC () »
DC
[] «
DC
DC
FACTS (FACTS⁽¹⁾)
DFACTS⁽¹⁾ (Distribution FACTS)
DC - UPQC
(D-STATCOM⁽¹⁾)
(DVR⁽¹⁾)
PCC⁽¹⁾
()
IF⁽¹⁾ [-]
UPQC [] UPQC
(PCC)
UPQC PSCAD/EMTDC UPQC
PWM⁽¹⁾
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6- Interface Filter
7- Pulse Width Modulation

1- Flexible AC Transmission System
2- Distribution FACTS
3- Distribution FACTS
4- Dynamic Voltage Restorer
5- Point of Common Coupling



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$$SPWM^{(1)} \quad (V_{cc}^{ref} \quad V_{cb}^{ref} \quad V_{ca}^{ref})$$

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$$) V_{out} (PCC \quad) V_{in}$$

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[1]

$$\vec{q}_l = \vec{v}_l \times \vec{i}_l = \begin{bmatrix} \vec{q}_a \\ \vec{q}_b \\ \vec{q}_c \end{bmatrix} = \begin{bmatrix} \vec{a} & \vec{b} & \vec{c} \\ v_a & v_b & v_c \\ i_{la} & i_{lb} & i_{lc} \end{bmatrix} = \begin{bmatrix} v_b & v_c \\ i_{lb} & i_{lc} \\ v_c & v_a \\ i_{lc} & i_{la} \\ v_a & v_b \\ i_{la} & i_{lb} \\ i_{lc} & i_{lb} \end{bmatrix} \quad (1)$$

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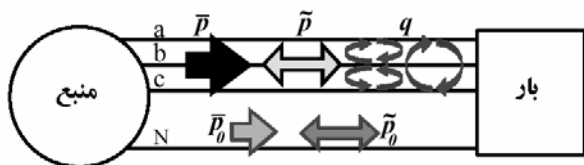
UPQC

$\vec{c} \quad \vec{b} \quad \vec{a}$

$\vec{q}_l \quad ()$

$$\vec{q}_l = (v_b i_{lc} - v_c i_{lb}) \vec{a} + (v_b i_{lc} - v_c i_{lb}) \vec{b} + (v_b i_{lc} - v_c i_{lb}) \vec{c} \quad (2)$$

$$\vec{v} = \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad \text{and} \quad \vec{i}_l = \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (3)$$



() [] $v_l \quad i_l$

$$p_l(t) = \vec{v} \cdot \vec{i}_l = v_a(t) \cdot i_{la}(t) + v_b(t) \cdot i_{lb}(t) + v_c(t) \cdot i_{lc}(t) \quad (4)$$

(i_{lp})

(i_l)

[] $v \quad i_l$

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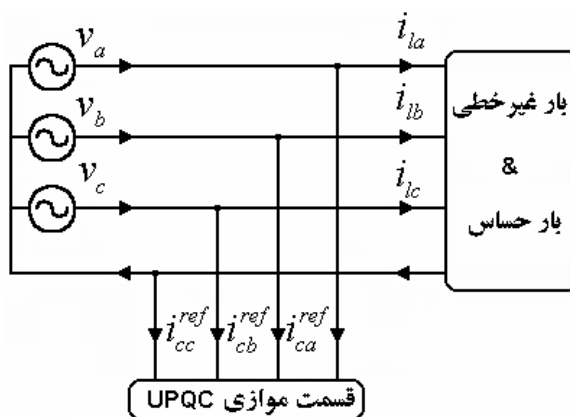
(i_{lq})

$$\vec{i}_l = \vec{i}_{lp} + \vec{i}_{lq} \quad (5)$$

$$\vec{i}_{lp} = \begin{bmatrix} i_{lap} \\ i_{lbp} \\ i_{lcp} \end{bmatrix} = \frac{p}{v \cdot v} \vec{v} \quad (6)$$

$$\vec{i}_{lq} = \begin{bmatrix} i_{laq} \\ i_{lbq} \\ i_{lcq} \end{bmatrix} = \frac{\vec{q} \times \vec{v}}{v \cdot v} \quad (7)$$

$$v \cdot v = v_a^2 + v_b^2 + v_c^2 \quad (8)$$



UPQC

$$\begin{aligned}
 & \mathbf{v} \times \mathbf{i}_p = \mathbf{0} \quad \mathbf{v} \cdot \mathbf{i}_{lq} = 0 \\
 & \mathbf{i}_q \quad \mathbf{v}_l \quad \mathbf{i}_p \quad \mathbf{i}_q \\
 & \text{UPQC} \\
 & \text{DC} \quad (p_{loss}) \\
 & PI \\
 & p_{loss} \quad \text{DC} \\
 & () \quad p_{l1}(t) \quad PI \\
 & () \\
 & DC \quad p_{loss} \\
 & \text{UPQC} \\
 & p_{shu}(t) \quad p_s(t) \\
 & p_{l1}(t) \quad \text{UPQC} \quad \text{PCC} \\
 & p_{lh}(t) \\
 & q_{lk} \quad q_{shuk} \\
 & k \\
 & () \quad () \quad (() \quad () \quad) \\
 & \text{UPQC} \\
 & () \\
 & \text{---} \\
 & \text{UPQC} \\
 & i_{ca} = i_{la} - \frac{\bar{p}_{l1} + p_{loss}}{v_{1a}^2 + v_{1b}^2 + v_{1c}^2} \cdot v_{1a} \\
 & i_{cb} = i_{lb} - \frac{\bar{p}_{l1} + p_{loss}}{v_{1a}^2 + v_{1b}^2 + v_{1c}^2} \cdot v_{1b} \\
 & i_{cc} = i_{lc} - \frac{\bar{p}_{l1} + p_{loss}}{v_{1a}^2 + v_{1b}^2 + v_{1c}^2} \cdot v_{1c} \\
 & () \\
 & [] \quad [] \\
 & \text{UPQC} \\
 & i_{ca} = i_{la} - \frac{\bar{p}_{l1}}{v_{1a}^2 + v_{1b}^2 + v_{1c}^2} \cdot v_{1a} \\
 & i_{cb} = i_{lb} - \frac{\bar{p}_{l1}}{v_{1a}^2 + v_{1b}^2 + v_{1c}^2} \cdot v_{1b} \\
 & i_{cc} = i_{lc} - \frac{\bar{p}_{l1}}{v_{1a}^2 + v_{1b}^2 + v_{1c}^2} \cdot v_{1c} \\
 & () \\
 & DC \\
 & DC \\
 & PI
 \end{aligned}$$

$$\begin{bmatrix} V_{ld}^{exp} \\ V_{lq}^{exp} \\ V_{l0}^{exp} \end{bmatrix} = T_{abc}^{dq0} \begin{bmatrix} V_{la}^{exp} \\ V_{lb}^{exp} \\ V_{lc}^{exp} \end{bmatrix} \quad ()$$

$$\begin{bmatrix} V_{la}^{exp} \\ V_{lb}^{exp} \\ V_{lc}^{exp} \end{bmatrix} = \begin{bmatrix} V_m \sin(\omega t) \\ V_m \sin(\omega t - 120^\circ) \\ V_m \sin(\omega t + 120^\circ) \end{bmatrix}$$

$$\begin{bmatrix} V_{cd}^{ref} \\ V_{cq}^{ref} \\ V_{c0}^{ref} \end{bmatrix} = \begin{bmatrix} V_{sd} \\ V_{sq} \\ V_{s0} \end{bmatrix} - \begin{bmatrix} V_{ld}^{exp} \\ V_{lq}^{exp} \\ V_{l0}^{exp} \end{bmatrix} \quad ()$$

a-b-c

$$\begin{bmatrix} V_{sd} \\ V_{sq} \\ V_{s0} \end{bmatrix} = T_{abc}^{dq0} \begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} = V_{s1p} + V_{s1n} + V_{s10} + V_{sh} \quad ()$$

$$= \begin{bmatrix} V_{s1pd} \\ V_{s1pq} \\ 0 \end{bmatrix} + \begin{bmatrix} V_{s1nd} \\ V_{s1nq} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ V_{s100} \end{bmatrix} + \begin{bmatrix} V_{shd} \\ V_{shq} \\ V_{sh0} \end{bmatrix} \quad ()$$

$$T_{abc}^{dq0} = \frac{2}{3} \begin{bmatrix} \cos(\omega t) & \cos(\omega t - 120^\circ) & \cos(\omega t + 120^\circ) \\ -\sin(\omega t) & -\sin(\omega t - 120^\circ) & -\sin(\omega t + 120^\circ) \\ 1/2 & 1/2 & 1/2 \end{bmatrix}$$

$V_{s10} \quad V_{s1n} \quad V_{s1p}$

V_{sh}

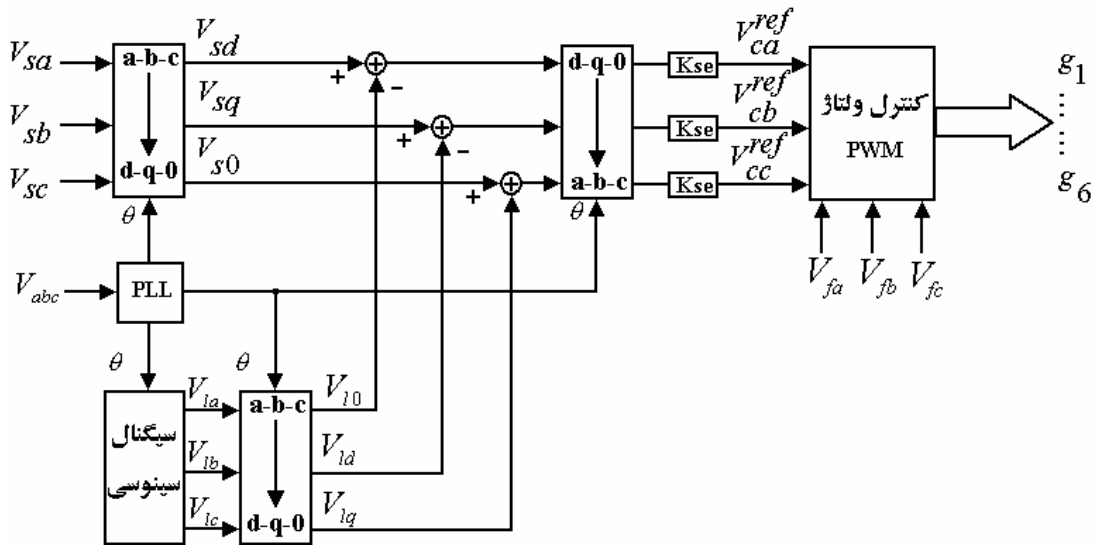
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d-q-0



UPQC

PCC ()
 PCC IEEE
 () PCC () () UPQC

$$L(t) = L_0 - \frac{D_1}{2} \cdot (1 + \sin(\Omega t)) \quad ()$$

Ω D_1 L_0 ()

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$$V_{arc} = sig(i) \cdot (V_{at} + \frac{C}{D + |I_{arc}|}) \quad ()$$

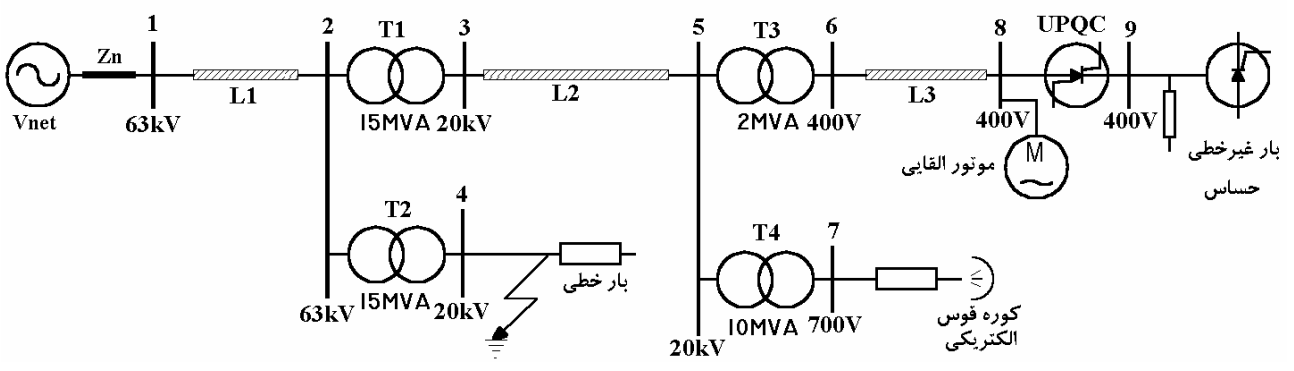
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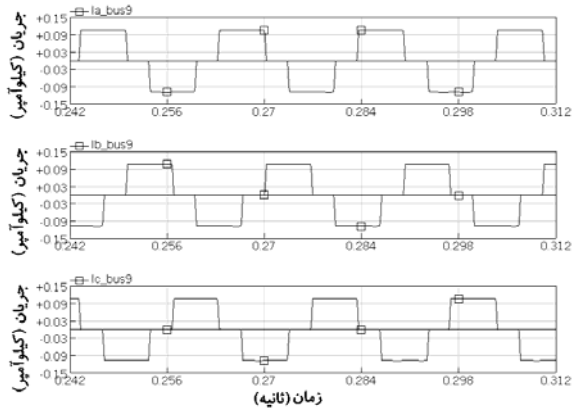
D C
 V_{at} I_{arc}

DC

$$V_{at} = A + B \cdot L \quad ()$$

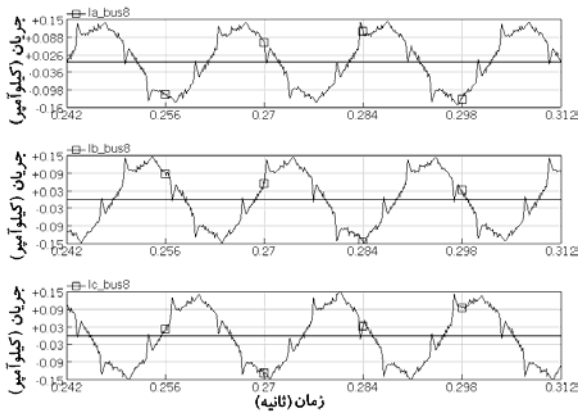
L A ()
 $B \cdot L$





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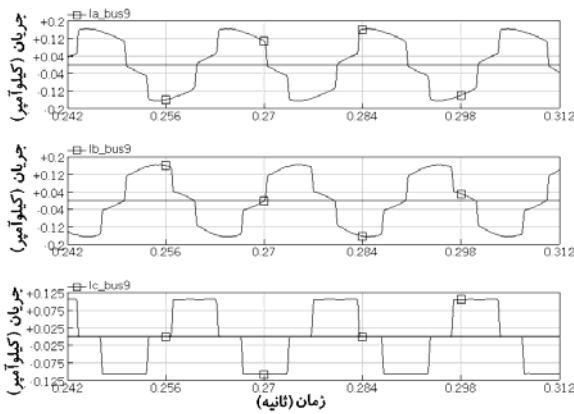
() PCC

UPQC

PCC

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PCC

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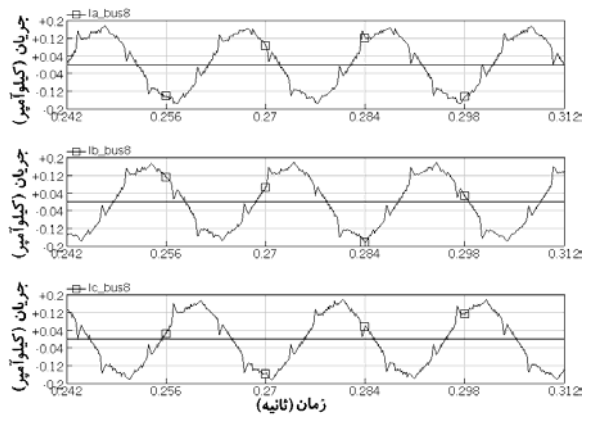
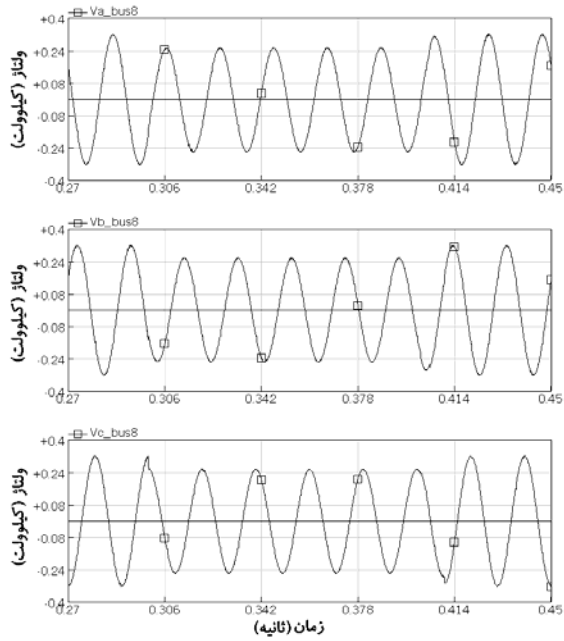
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UPQC

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UPQC

UPQC



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PCC

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DC

(p_{loss})

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DC

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DC

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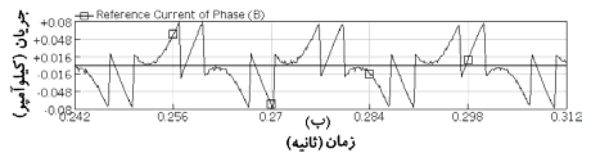
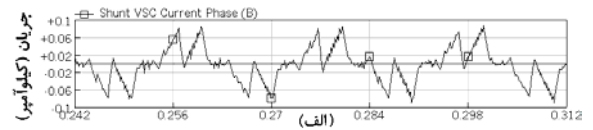
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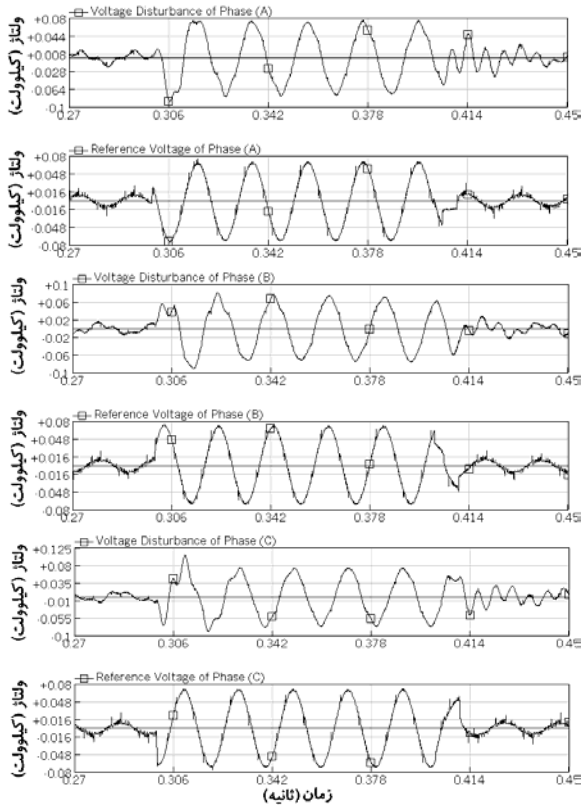
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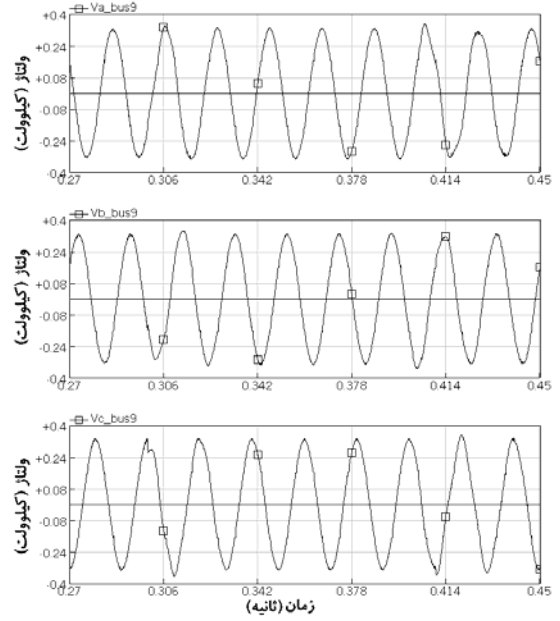
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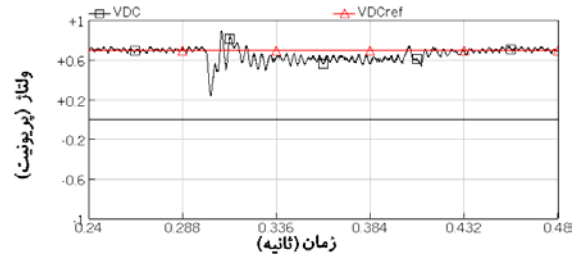
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UPQC



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DC

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$(U_{cc} \quad U_{cb} \quad U_{ca})$

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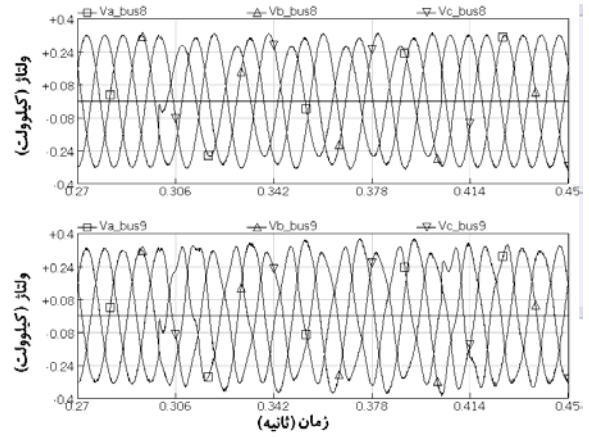
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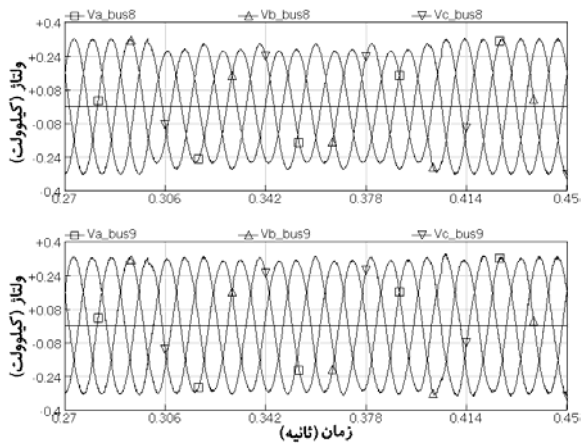


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L1



(Z_0)

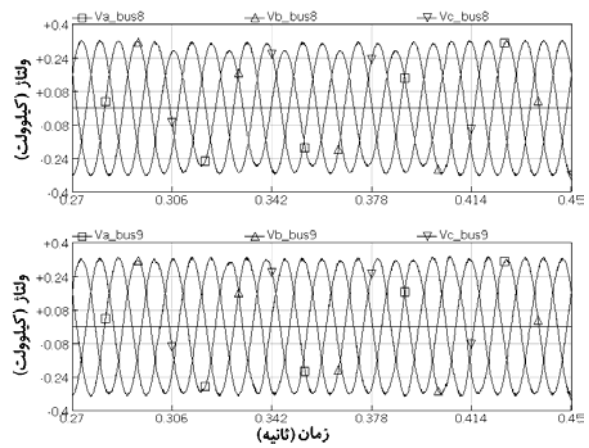
(Z_1)

(Z_2)

($Z_1 + Z_2 + Z_0$)

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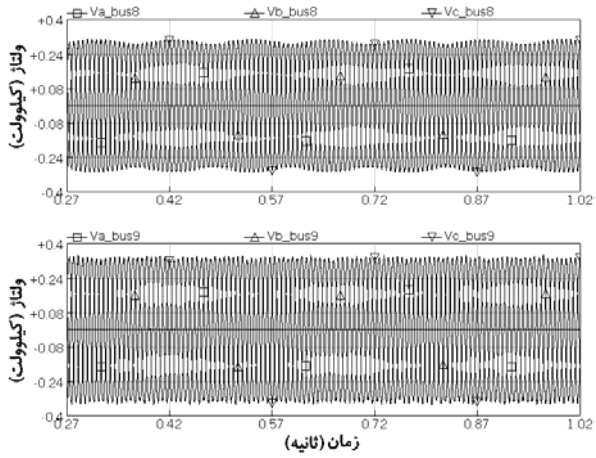
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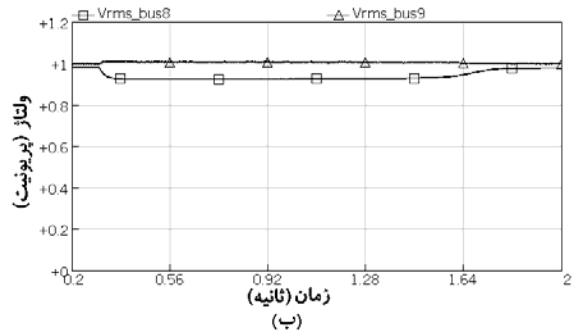
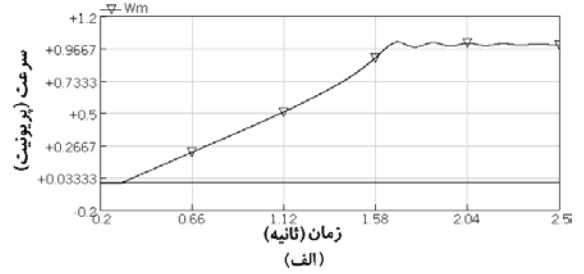
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