Performance Analysis on Power Flow of a Three-feeder/Multi-bus Distribution System using GUPQC

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***Abstract*- In this paper, the power flow analysis through the GUPQC connected to the multi-bus/3-feeder distribution systems was distributed. a replacement controller theme for the series compensator of GUPQC supported the d-q theory to complete the supply facet voltage harmonics, voltage sag/swell and interruption was conferred. the applying of the planned controller to complete voltage imperfections of the network and for the development of the ability quality of the client masses was valid by the simulation results. Depth simulation studies were distributed by exploitation MATLAB/SIMULINK computer code to determine the power of the GUPQC to enhance power quality of the distribution systems underneath distorted offer voltage conditions.**

Key Word- Unified Power Quality Conditioner (UPQC); Distribution System; Generalized Unified Power Flow Controller;

1. Introduction

In today's world, there's nice importance of current as a result of it's that the foremost notable sort of energy and everybody are massively relying on it. whereas not give of electricity life can't be unreal [1]-[3]. At an identical time, the quality and endlessness of the power equipped are in addition vital for the economical functioning of the highest user instrumentality. many of the business and industrial plenty would like high quality undisturbed and constant power. so maintaining the qualitative power is high very important in today’s world. because of power natural science devices there's a significant impact on quality and endlessness of electrical give. thanks to power natural science devices, there's uninterrupted power give, flicker, harmonics, and voltage fluctuations etc., there's in addition PQ problems like voltage rise/dip because of network faults, lightning, amendment of capacitance banks [4]. With the excessive uses of non-linear load (computer, lasers, printers, rectifiers) there's reactive power disturbances and harmonics in power distribution system. It's really essential to beat this kind of problems as its impact may increase within the future associated cause an adverse result. traditionally passive filters were used for reactive power disturbances and harmonics generation but there are many problems with them like they're large in size, resonance draw back, and impact of provide physical phenomenon on performance [5].

The smart Grid thought and its implementation encompasses a major influence on the trendy multi-feeder distribution system. Power quality (PQ) is that the major concern of the distribution system users relating to the appliance of sensitive essential plenty [6]. At the same time, wholly sinusoidal voltage and currents with a seamless frequency is critical for constant industrial sectors for the right production methodology [7]. The reliability of the operation of sensitive essential plenty that doesn't tolerate disturbances inside the supplier system is really supported power offer quality. By integration power electronic converters-based custom power devices inside the present distribution give systems, it's getable to supply artless top of the range power to sensitive plenty in industrials or business centers. therefore on beat the PQ connected problems, a unified power quality conditioner (UPQC) [1-3], by victimization series ANd shunt active power filters are planned to mitigate voltage and current imperfections in an passing single-feeder distribution system. sadly, the UPQC cannot provide power quality solutions for multi-bus/multi-feeder distribution systems [8].

Based on the thought and applications of the versatile AC transmission systems (FACTS), devices in transmission lines the thought of the interline power flow controller (IPFC) and conjointly the generalized unified power flow controller (GUPFC) [4, 5] is extended to the multi-bus/multi-feeder distribution systems. on the same lines, extended version of the road IPFC illustrious as-as Associate in Nursing interline unified power quality conditioner (IUPQC) consisting of two VSCs, one within the shunt to manage the bus voltage of the one feeder in distribution system and conjointly the opposite within the series to regulate the voltage across a sensitive load of the alternative feeder, was planned in [9]. A multi-converter unified power quality conditioner (MC-UPQC) having three VSCs connected consecutively through a regular.

DC-link capacitance was rumored in [10] to finish every this and voltage imperfections in one feeder and conjointly the voltage imperfections among the alternate feeder. associate degree extended version of line GUPFC is planned in [8] for PQ improvement of a multi-bus/ 3-feeder distribution system called, GUPQC that was completed by three VSCs connected consecutively by a regular DC-link capacitance on the DC facet. By coupling three VSCs in consecutive configurations the GUPQC is working with extra flexibility and allow the active power to current from one VSC to the other to spice up PQ of 3-feeder/multi-bus distribution system. to cash in on the exchange of power between the feeders, one among the VSCs among the GUPQC system was connected in shunt to a feeder through a coupling device and conjointly the choice a pair of VSCs, each nonparallel with a feeder, are connected to the other a pair of feeders through series injection transformers [11]. By this affiliation, the planned GUPQC will at constant time compensating voltage and current imperfections in multi-bus/3-feeder DS. Besides that, the power is transferred from one feeder to various feeders to finish voltage and current quality problems with the system [12].

This gift work has self-addressed the ability flow analysis and compensation performance of the GUPQC connected to a multi-bus/3-feeder distribution system supported the planned new controller strategy for series compensators [13].

2. GUPQC Topology

A multi-bus / three-feeder distribution system that has a sensitive nonlinear load (load1) by feeder1 and a pair of other sensitive a whole bunch (load2 and load3) connected to the other 3 feeders shown in figure one. each feeder is delineated by the equivalent resistance that denoted by ZS. The shunt compensator, VSC1 is working as a controlled current offer that utilised to compensate the harmonic currents of feeder1, the reactive power required by the load1 and to support the $64000 power needed by the two series compensators. At the identical time, the DC-link device voltage is to be maintained at the specified level [14].

The 2 series compensators, VSC2 and VSC3, are used as controlled voltage sources to safeguard the two sensitive a whole lot (load2 and load3) against voltage imperfections. each of the series compensators is supposed to provide the missing voltage between the availability side and so the best load facet voltages such the load bus voltage of the individual feeder is usually curved and at the specified level [16], [17].

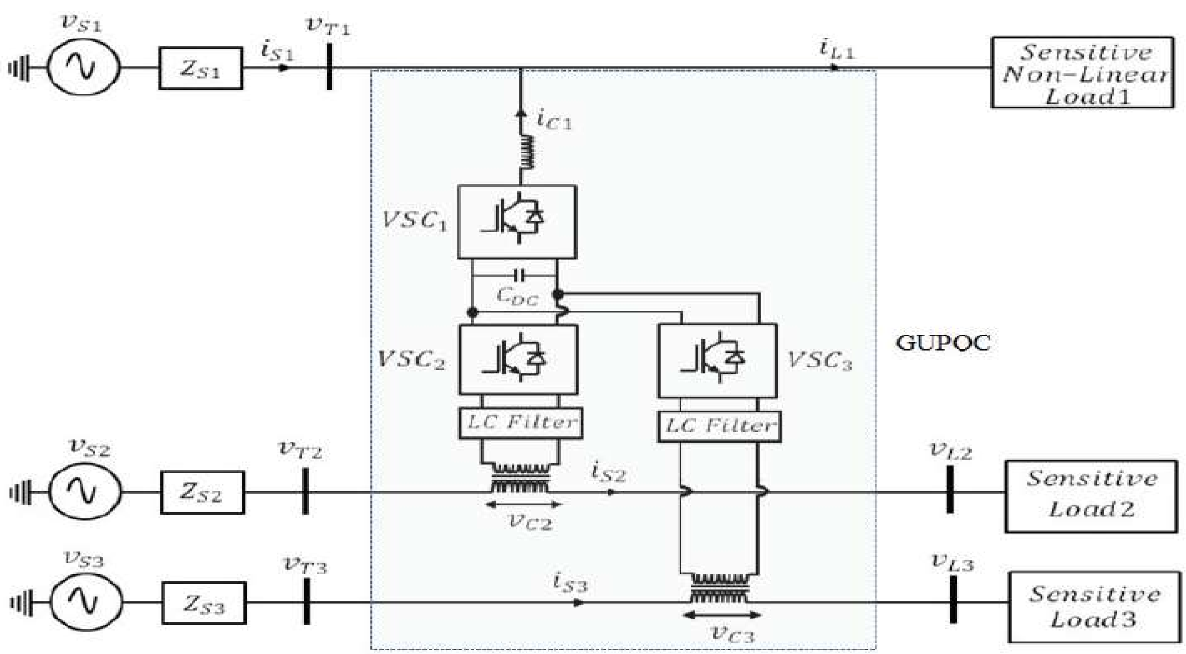

Figure 1. GUPQC connected to multi-bus/3-feeder distribution system

3. Power Flow Analysis

The power flow analysis was meted out underneath traditional and disturbed conditions of the feeders supported the basic elements of voltage and current [18]. Supported Figure 2 by considering the insulation power issue masses on the feeders, the load voltages and currents will be written as shown in (1) and (2) respectively:

vLn=VLn∠0° (1)

iLn= ILn∠−ϕLn (2)

Where, the feeder index n =1, 2, or 3. In case of system voltage sag/swell etc., the source voltage fluctuation factor, x_n can be defined by (3).

$$x_n = \frac{V_{Sn}-V_{in}}{V_{Ln}} \quad (3)$$

Then, the injected voltage by the series compensators can be calculated by (4).

$$V_{Cn} = V_{Ln} - V_{Sn} = x_n V_{Ln} < 0° \quad (4)$$

Under consideration of the lossless power of GUPQC system, the active power demanded by the masses ought to be capable the active power equipped by the sources [19]. Then, the system active power is expressed by exploitation equation (5):

$$V_{Sn}I_{Sn} = V_{Ln}(1 + x_n)I_{Sn} = V_{Ln}I_{Ln}cos\varphi_{Ln} \quad (5)$$

Thus, the source current becomes:

$$I_{Sn} = \frac{I_{Ln}}{(1+x_n)}cos\varphi_{Ln} \quad (6)$$

From (6) bothI_Lnandφ_Lnare constant for a selected form of load [20]. Thus, the supply current depends on the source voltage fluctuation factors. If the provision facet voltage of feeder2 or feeder3 is subjected to the voltage sag/swell etc., the feeder1 supply current are often expressed as:

$$I_{S1} = \frac{I_{L1}}{(1+x_n)}cos\varphi_{L1} - \frac{x_2V_{L2}I_{L2}}{(1+x_2)V_{L1}}cos\varphi_{L2} - \frac{x_3V_{L3}I_{L3}}{(1+x_2)V_{L1}}cos\varphi_{L3} \quad (7)$$

The compensation current by the shunt compensator which incorporates active and reactive current elements is expressed by (8):

$$I_{c1} = I_{S1} - I_{L1}\angle - \varphi_{L1} = (I_{S1} - I_{L1}\, cos\varphi_{L1}) + j(I_{L1}\, sin\varphi_{L1}) \quad (8)$$

Then, the complex power of the shunt compensator is:

$$S_{VSC1} = V_{L1}I_{C1} = V_{L1}(I_{S1} - I_{L1}\, cos\varphi_{L1}) + j(V_{L1}I_{L1}\, sin\varphi_{L1}) \quad (9)$$

$$P_{VSC1} = V_{L1}(I_{S1} - I_{L1}\, cos\varphi_{L1}) \quad (10)$$

$$Q_{VSC1} = V_{L1}I_{L1}\, sin\varphi_{L1} \quad (11)$$

Feeder2 compensator, VSC2, active and reactive powers:

$$P_{VSC2} = -x_2V_{L2}I_{L2}\, cos\varphi_{L2} \quad (12)$$

$$Q_{VSC2} = x_2V_{L2}I_{L2}\, sin\varphi_{L2} \quad (13)$$

Feeder3 compensator, VSC3, active and reactive powers:

$$P_{VSC3} = -x_3V_{L3}I_{L3}\, cos\varphi_{L3} \quad (14)$$

$$Q_{VSC3} = x_3V_{L3}I_{L3}\, sin\varphi_{L3} \quad (15)$$

Based on the on top of active and reactive power equations, the ability flow within the three feeders Associate in Nursing analysis was meted out in the following case studies to indicate the power of the GUPQC to maintaining the general power balance in an exceedingly multi-bus/3-feeder distribution system [21].

Within the traditional operation condition of most of the distribution systems, the utility equipped the load active and reactive power demand, that puts an additional burden on the supply to provide the load reactive power as seen in Figure 3, 4, 5 and 6.

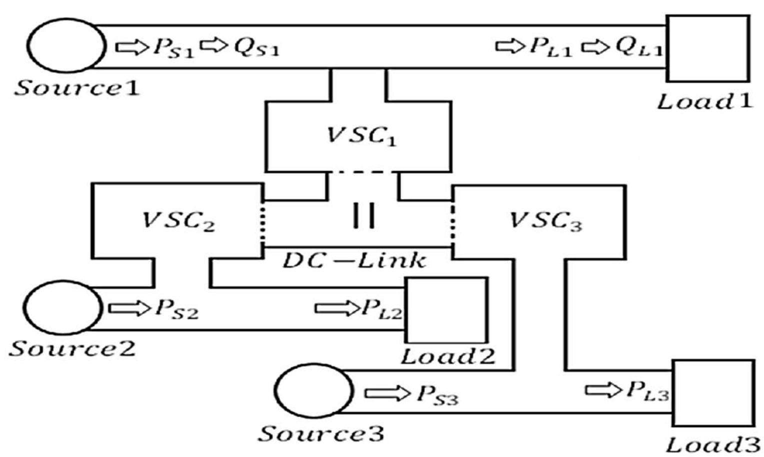

Figure 2. Normal operation condition: GUPQC-OFF

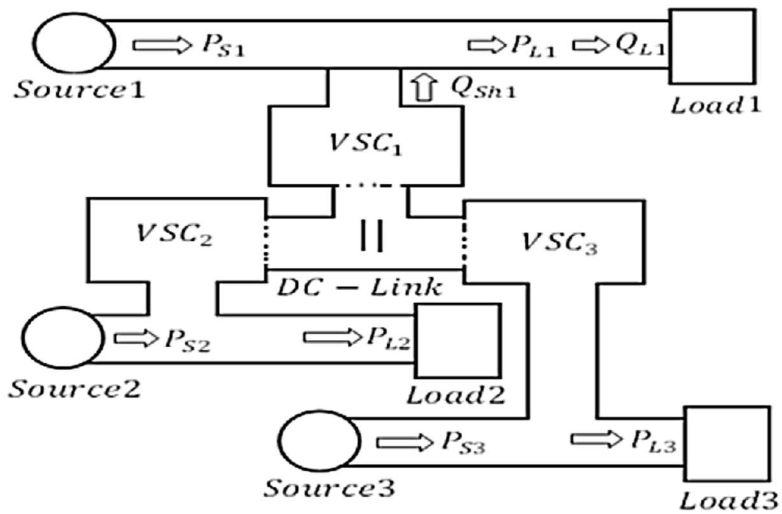

Figure 3. Normal operation condition: GUPQC-ON

As the GUPQC comes into the operation, and under assumption of, x_2= x_3= 0, i.e. *VSn*=*VLn* based on (13), (14) and (15), Q_{VSC} = *QL*1 =*Qsh*1 andP_{VSC2} = P_{VSC3}which means that the reactive power needed by sensitive nonlinear load1, is equipped by the shunt compensator such no further reactive power burden is placed on the source1 throughout the voltage imperfections in feeder2 or feeder3. Fig. 3 shows the facility flow during this case [23], [24].

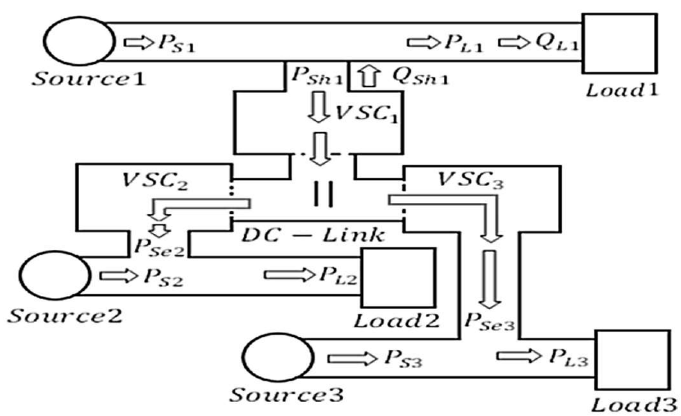

Figure 4. GUPQC-ON: Voltage Sag condition

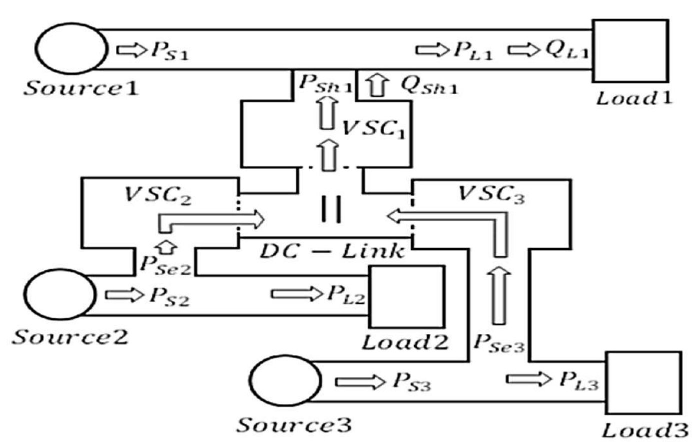

Figure 5. GUPQC-ON: Voltage swell condition

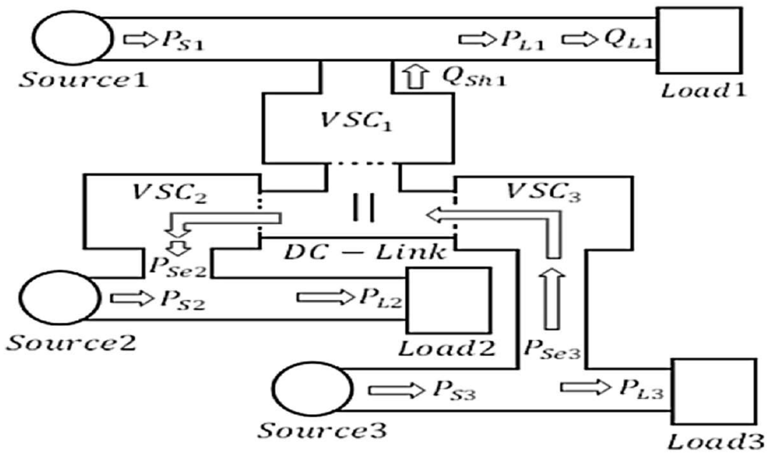

Figure 6. GUPQC-ON: Voltage Sag/swell condition

4. Control of GUPQC

Different controller strategies to manipulate the collection and shunt compensators of the UPQC have been proposed as introduced in [25-28]. Most of the proposed controllers are used to discover voltage or contemporary disturbances under regular kingdom conditions. However, below dynamic operation conditions, a few of them confirmed desirable response however too complex to implement. This is because of the actual fact an in depth computing time is needed to implement. during this thesis, the estimation of the reference alerts for the sequence compensator of GUPQC has been calculated primarily based whole on the synchronous coordinate system transformation. whereas for the shunt compensator, the generalized non-active electricity plan (GNPT) [10] has been wont to estimate the reference compensation currents [29], [30].

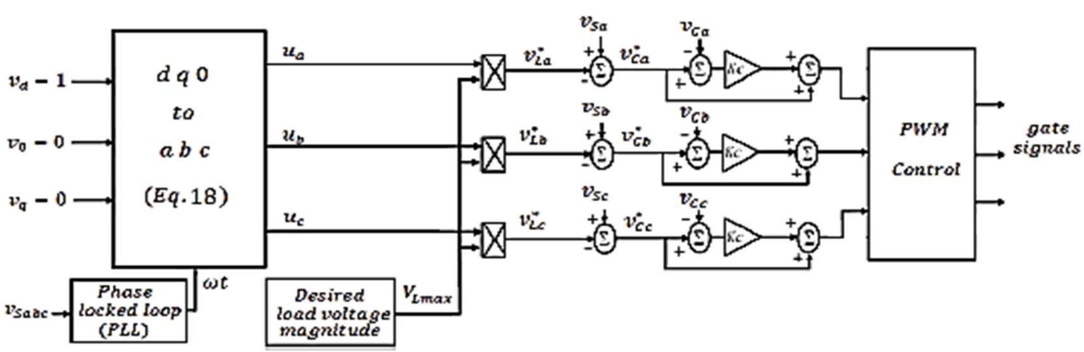

Figure 7. Proposed control scheme of the series compensator: block diagram

The reference compensation indicators to control the GUPQC collection compensators have been derived by way of the use of the proposed technique primarily based on the synchronous reference frame [31], [32]. The proposed collection compensator controller used to be used to manipulate the GUPQC in order to inject in-phase voltage with the supply facet current. This used to be done to ensure that the touchy loads (load 2 and load 3) acquired pure sinusoidal voltage with constant amplitude and frequency even when the furnish aspect voltage of the 2 feeders was once both completely distorted and subjected to the voltage sag/swell or interruptions [33]. To recognize the proposed collection compensator controller algorithm, solely the d-axis voltage in the synchronous rotating frame was once considered and given a unity value. Both q and 0 axis elements were equalized to zero. By applying d-q-0 to a-b-c transformation below this assumption, 3-phase balanced unity sinusoidal voltages had been generated as proven in (16) [34].

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin(\omega t) & \cos(\omega t) & 1 \\ \sin(\omega t - 120^*) & \cos(\omega t - 120^*) & 1 \\ \sin(\omega t + 120^*) & \cos(\omega t + 120^*) & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \tag{16}$$

From the generated sinusoidal voltages in (16), and by using the maximum voltages of load 2 or load 3, the desired load 2 or load 3 voltages were derived as shown (17).

$$v_{La}^{*} = u_a \,.V_{L\,max} \;=\; V_{L\,max}\sin(\omega t)$$
$$v_{Lb}^{*} = u_b \,.V_{L\,max} \;=\; V_{L\,max}\sin(\omega t -\; 120^{*})$$
$$v_{Lc}^{*} = u_c \,.V_{L\,max} \;=\; V_{L\,max}\sin(\omega t +\; 120^{*}) \quad (17)$$

The reference compensation voltages were obtained by comparing the measured distorted feeder 2 and feeder 3 source side voltages with the desired load side voltages as:

$$v_{Ca}^{*} = \; v_{sa} - \; v_{La}^{*}$$
$$v_{Cb}^{*} = \; v_{sb} - \; v_{Lb}^{*}$$
$$v_{Cc}^{*} = \; v_{sc} - \; v_{Lc}^{*} \quad (18)$$

In order to generate adequate gating patterns to prompt the IGBT switches of the GUPQC series compensators, the calculated reference voltages (18) have been in contrast with the measured genuine sequence compensator output voltages while the error signal was processed using the expanded sinusoidal pulse width modulation (SPWM) approach as shown in Figure 7. The estimation of the reference compensation alerts for the GUPQC shunt compensator was primarily based on the GNPT as illustrated in Figure 8. The voltage and present-day vectors in m-phase systems can be outlined by means of (19) and (20):

$$i(t) = [t_1(t), t_2(t), \ldots . t_m(t)\;]^T \quad (19)$$

$$v(t) = [v_1(t), v_2(t), \ldots . v_m(t)\;]^T \quad (20)$$

Based on GNAPT theory, the instantaneous power, p(t), and the average power P(t), over the averaging interval [t-T$_c$, t] could be calculated as:

$$p(t) = \; v^T\;(\mathrm{t})\;\mathrm{t}\;(\mathrm{t}) \;=\; \sum_{\mathrm{k=1}}^{\mathrm{m}} \mathrm{v_k}\;(\mathrm{t})\mathrm{i_k}\;(\mathrm{t})$$

$$p(t) = \; \frac{1}{Tc}\int_{t-T_c}^{t} p(\tau)d\tau \quad (21)$$

The resolution method of the averaging interval, (Tc) was once based on the application of GNPT as defined in [10]. Based on the GAPT, the cutting-edge issue that includes the lively strength and in-phase with the voltage is recognized as the energetic currenti_a (t) [35]. Both the instantaneous energetic present day and non-active currenti_n (t) is defined as:

$$P_a(t) = v^T\;(t)t_a\;(t) = \; \sum_{k=1}^{m} V_k(t)i_{ak}\;(t) \quad (22)$$

$$P_n\;(t) = \; v^t(t)\;t_n(t) = \; \sum_{k=1}^{m} v_k\;(t)t_{nk}\;(t) \quad (23)$$

Similarly, the corresponding average active power, $P_a(t)$, and the average non-active power, $P_n(t)$, over an average in the interval [t-T$_c$, t] are calculated as:

$$P_a(t) = \; \frac{1}{T_c}\int_{t-Tc}^{t} P_a(\tau)d\tau \quad (24)$$

$$P_n(t) = \; \frac{1}{T_c}\int_{t-Tc}^{t} P_n(\tau)d\tau \quad (25)$$

The *RMS* values of the voltage, $V_a(t)$, as well as the active current, $i_a\;(t)$, and the non-active current, $i_n(t)$, have been defined, respectively, as:

$$V_a(t) = \sqrt{\frac{1}{T_c}\int_{t-T_c}^{t} v_a^T\;(\tau)v_a\;(\tau)d\tau} \quad (26)$$

$$I_a(t) = \sqrt{\frac{1}{T_c}\int_{t-T_c}^{t} t_a^T\;(\tau)t_a\;(\tau)d\tau}$$

$$I_n(t) = \sqrt{\frac{1}{T_c}\int_{t-T_c}^{t} t_n^T\;(\tau)t_n\;(\tau)d\tau} \quad (27)$$

In the proposed controller of GUPQC shunt compensator as proven in Figure 8, firstly, the common strength has calculated the use of (21) with the help of the cohesion voltages (ua, ub, uc) which are generated from the sequence compensator control as in (16). The calculated common power, together with the RMS value of the load voltage (26) is used to calculate the active cutting-edge component, ia (t), primarily based on (19). The shunt compensator is employed to compensate for present-day distortions, supply the reactive strength required by the load1, guide the actual electricity required by means of the collection compensators and to hold the DC-link capacitor voltage at a favored level. To attain these objectives, the voltage of the DC-link capacitor was measured and compared with the reference fee whilst the error sign was once processed by using the usage of PI controller [36].

The output of the PI controller alongside with the estimated energetic current thing was once used to calculate the components of the non-active current $i_n(t)$, based on (20) which representing the reference compensating currents for the shunt compensator [37].

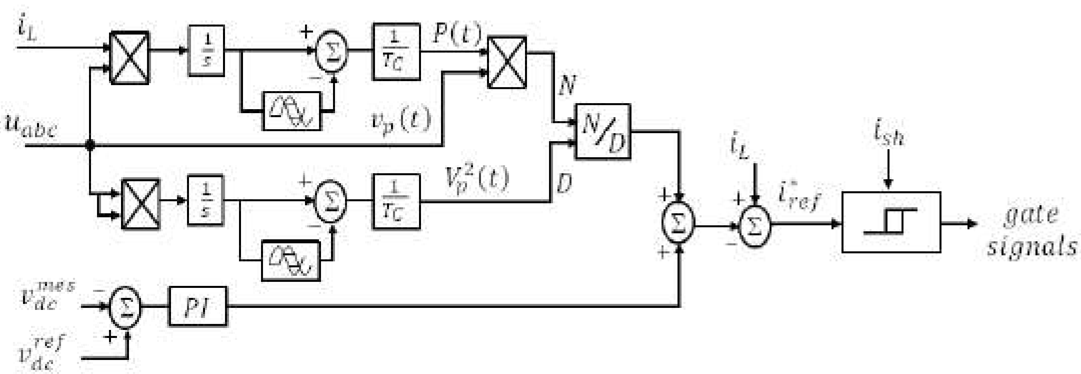

Figure 8. Control scheme of the shunt compensator: block diagram

The calculated reference compensating currents together with the measured actual shunt compensator output current was then processed by using the hysteresis band PWM controller to generate the gating signals for the shunt compensator IGBTs switches [38].

5. Simulation and Test Results

The simulation model of GUPQC test model in MATLAB/SIMULINK platform is illustrated as in Figure 9.

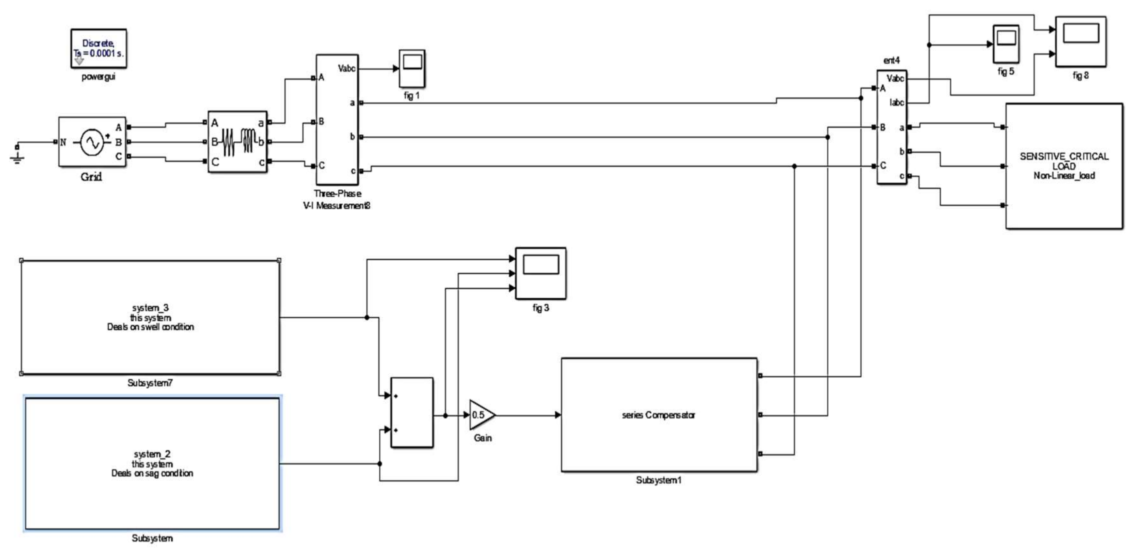

Figure 9. Simulation model of GUPQC system in MATLAB/SIMULINK platform

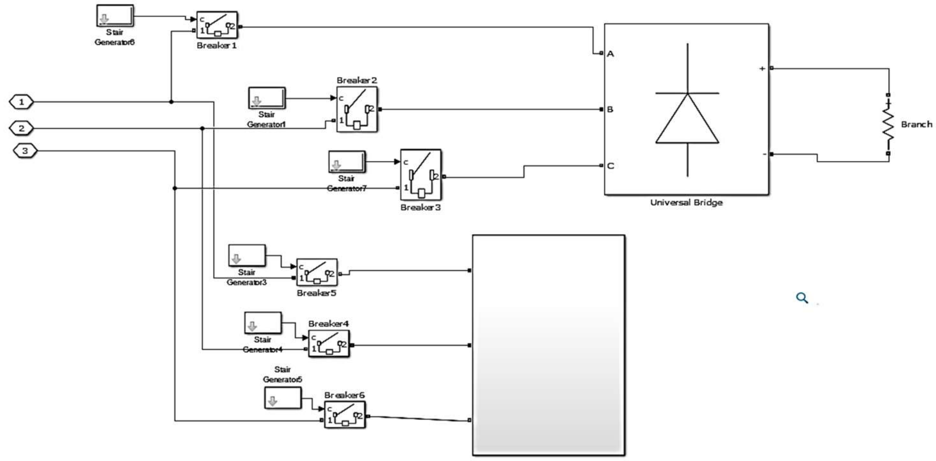

Figure 10. Simulation model of SVPWM &Sensitive Critical Load system in MATLAB/SIMULINK platform

As the sensitive nonlinear load1 could be a combination of linear and non-linear hundreds, ab initio the linear half was connected to the system. The shunt compensator was place into the operation at t1=0.10s as seen in Figure eleven and figure twelve, straight off started injecting the compensation currents, i.e., non-active current element. To complete current harmonics, the non-linear a part of the sensitive nonlinear load1 was connected at t2 = zero.15s.

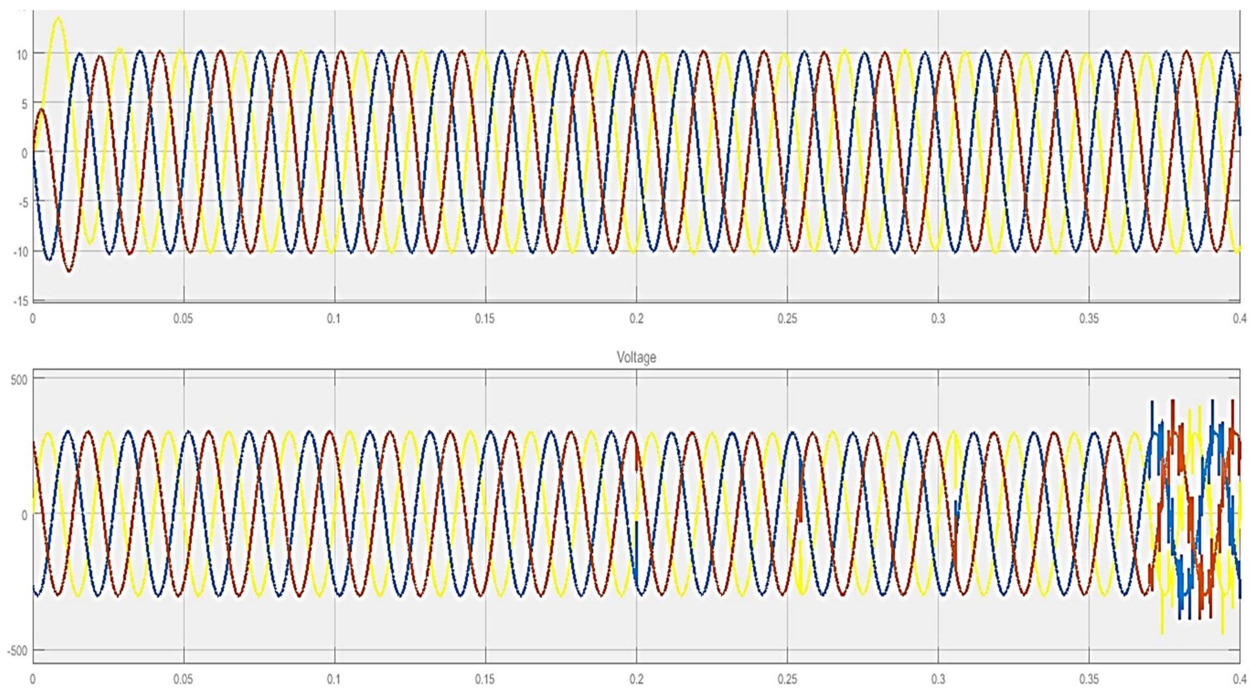

Figure 11. Final source voltage, source side current and compensation current

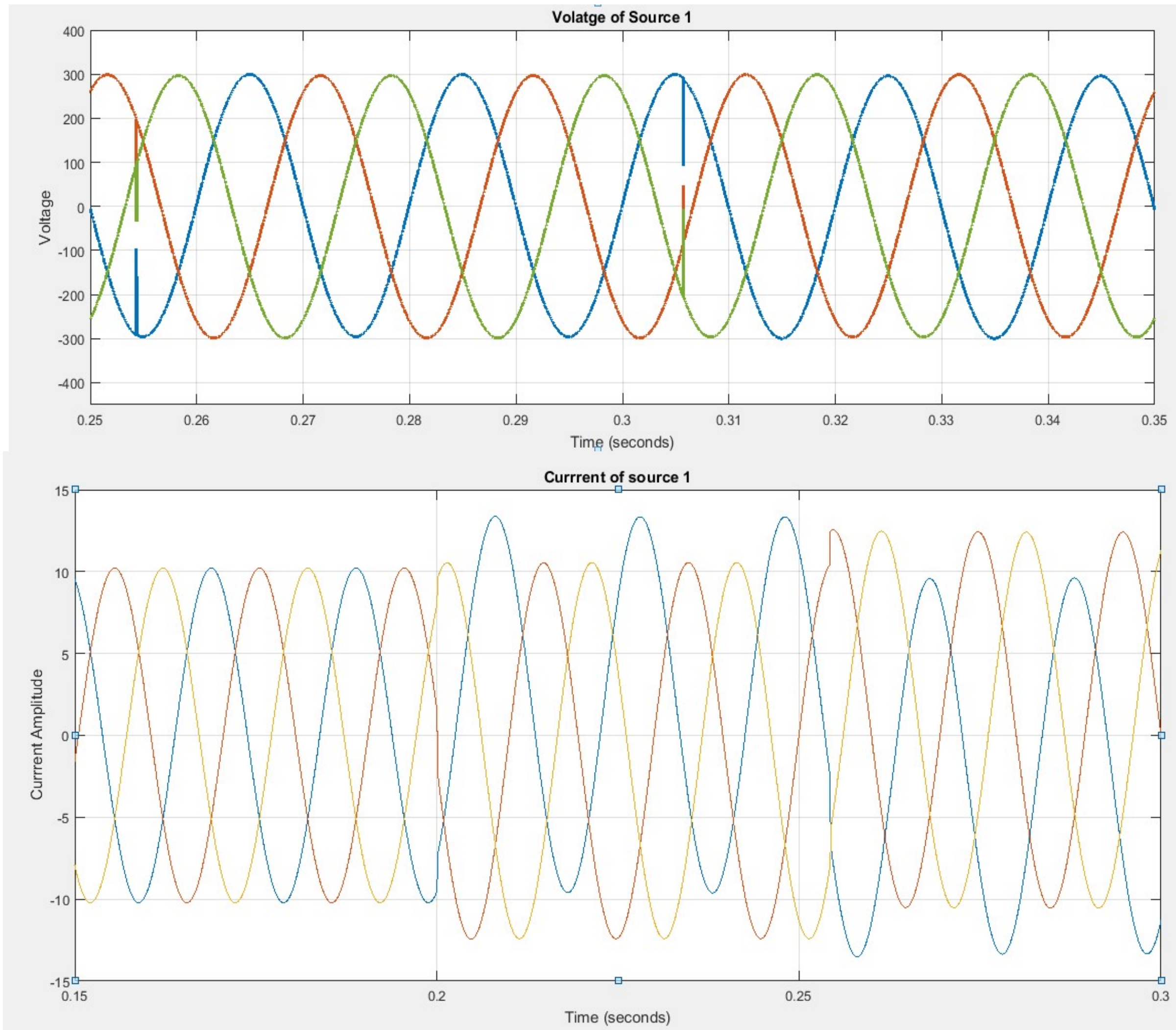

Figure 12. Source Voltage, Source Side Current

Source voltage and current supply facet current and compensation current with none condition are shown in figure thirteen and fourteen. The distortion of the provision voltages besides the voltage sag/swell was salaried with glorious compensating characteristics of the GUPQC supported the planned controller. The response of the shunt compensator to the changes within the system voltages (power flow) was conferred as in Figure fifteen in terms of the supply facet current of feeder1 and DC-link condenser voltage. doctor's degree level of the supply and cargo voltages are shown in figure sixteen in Figure seventeen shows doctor's degree level of the source and load voltages by GUPQC with svm. doctor's degree level of the supply and cargo voltages shown in figure eighteen.

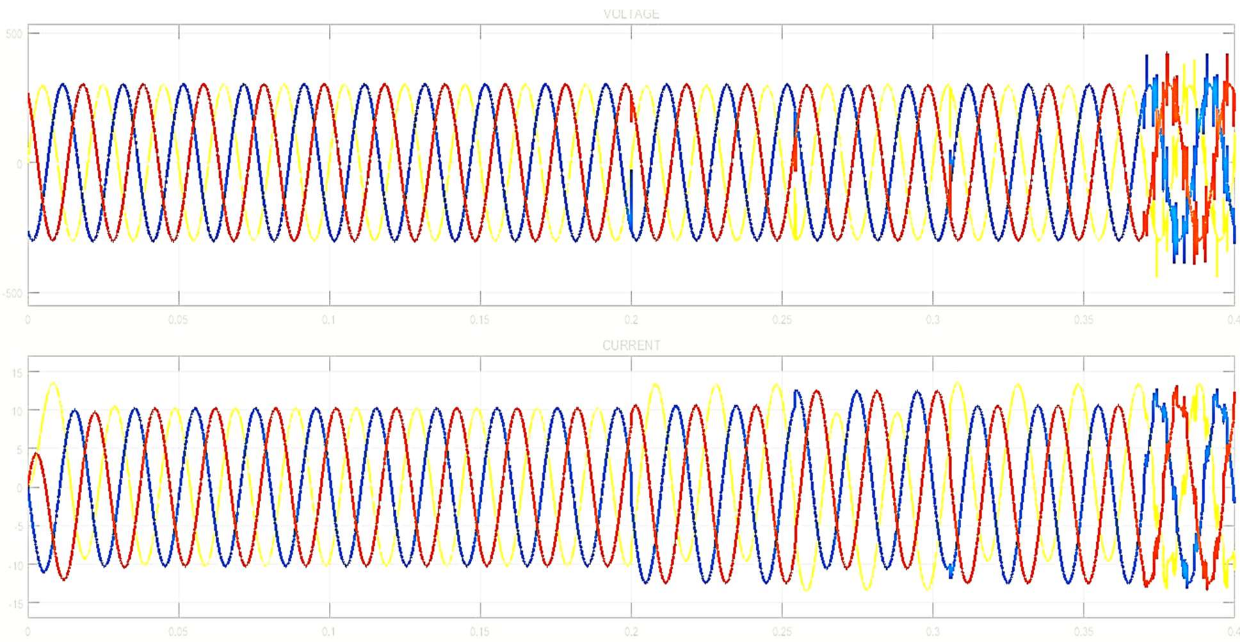

Figure 13. Source voltage, source side current and compensation current without any condition

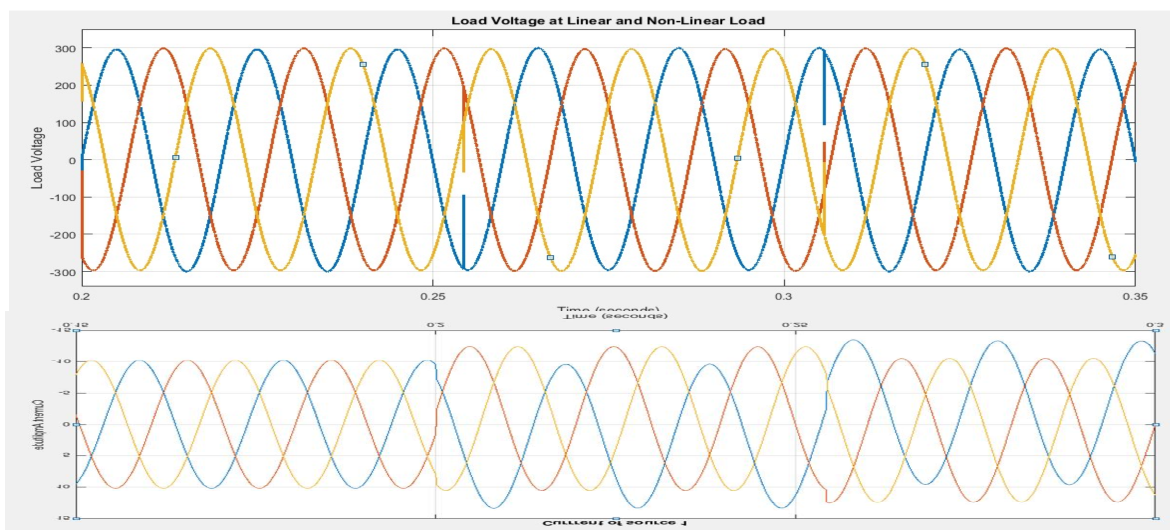

Figure 14. Source voltage, source side current and compensation current without any condition

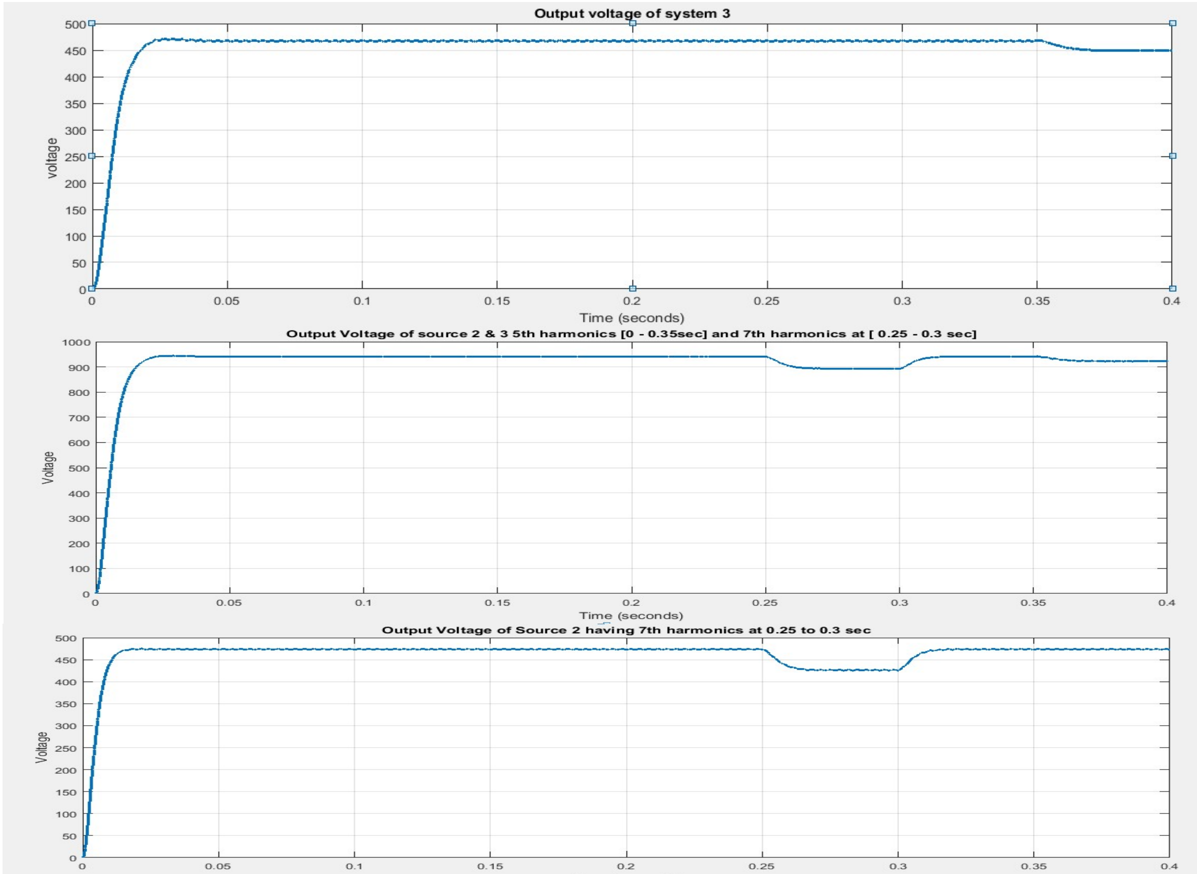

Figure 15. Source voltages with condition

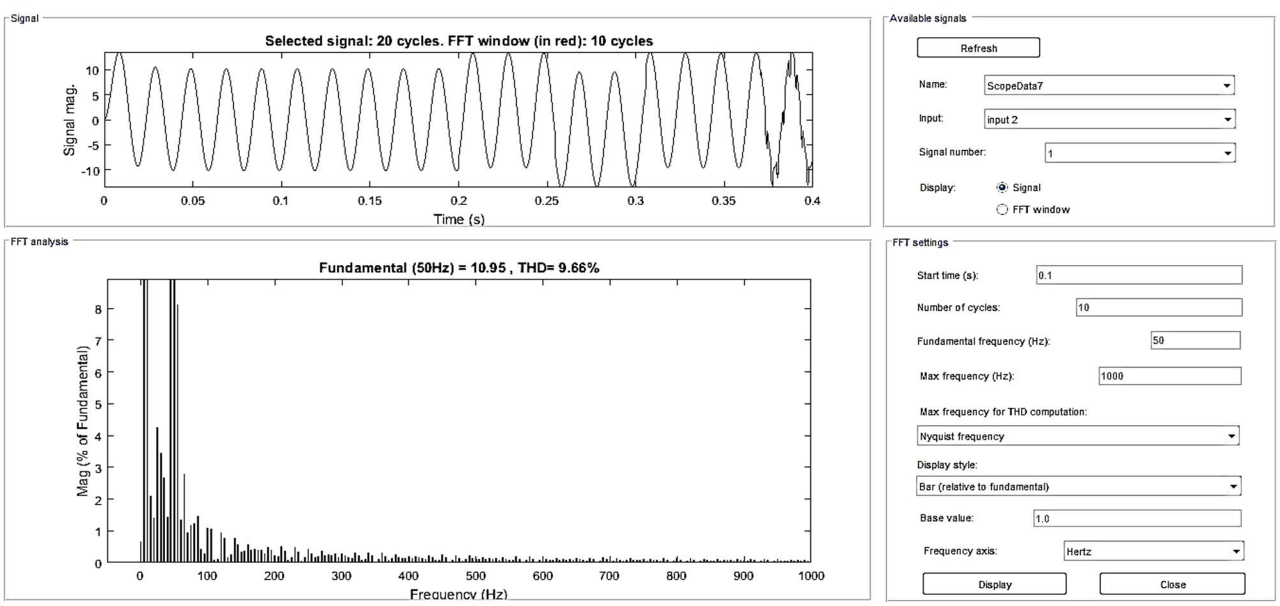

Figure 16. THD level of the source and load voltages

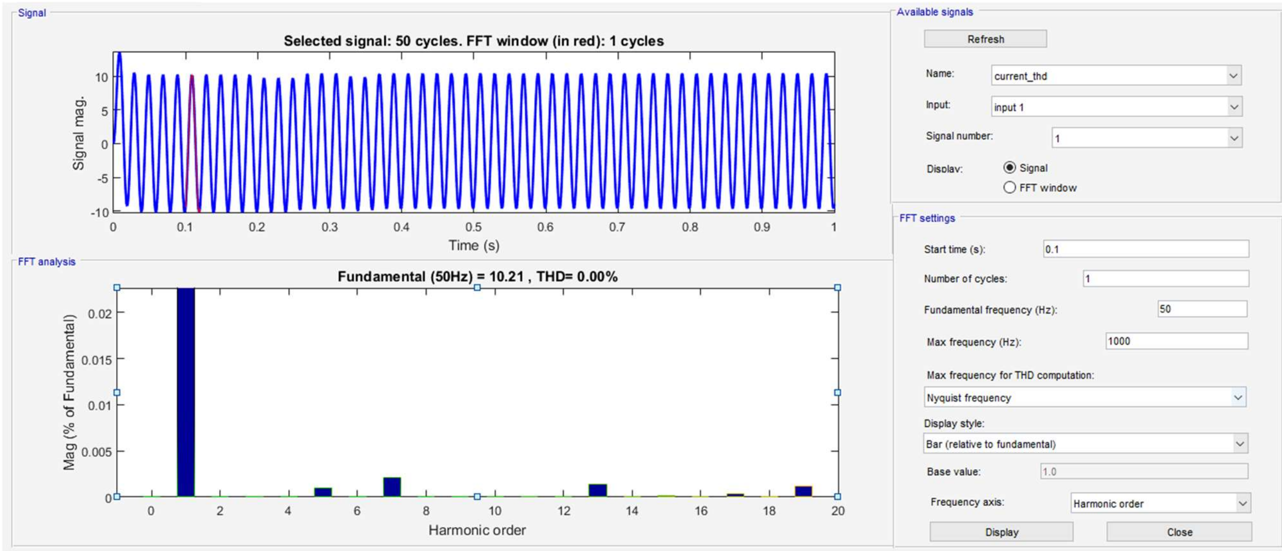

Figure 17. THD level of the source and load voltages by GUPQC with svm

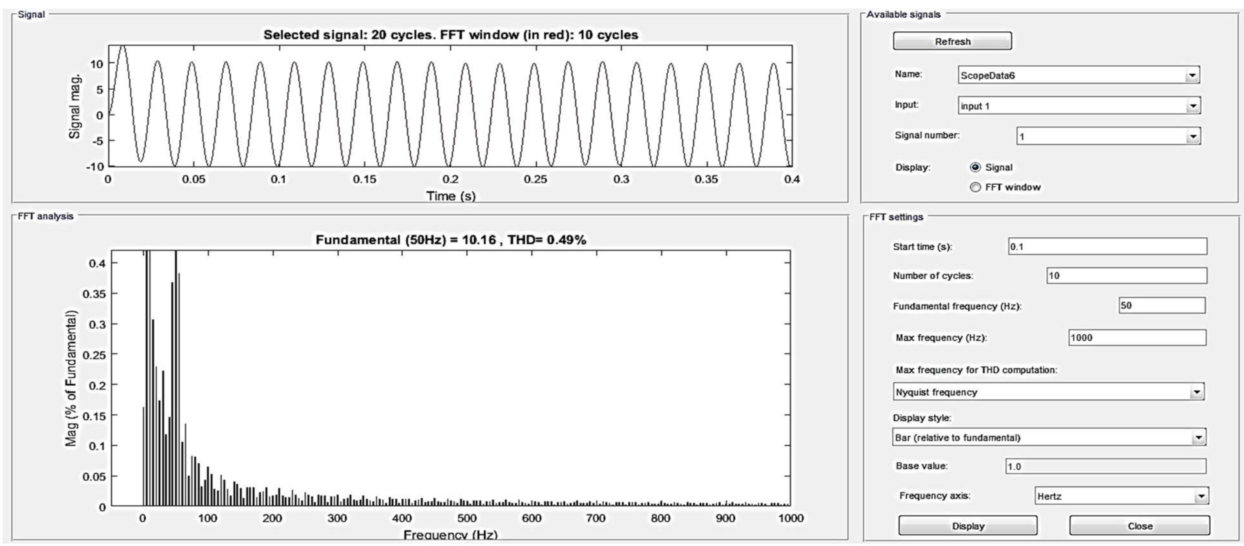

Figure 18. THD level of the source and load voltages

6. Conclusion

In this paper analyzed power flow analysis and control schemes of GUPQC method with mathematical observation. The multi-bus / 3-feeder distribution system in this system including GUPQC model method is explained in this paper. Also explains as the overview of power supply quality and its problems. Thesis concepts and apply techniques are discussed. The application of the controller to atone for voltage imperfections of the network and for the development of the ability quality of the client masses was valid by the simulation results. it's additionally been incontestible that the shunt compensator supported the developed controller effectively maintained the ability balanced beside the DC-link condenser at the specified level.

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