International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064

Custom Power Improvement in Distribution System by Open UPQC

P. Kondala Rao[1], K. Vimala Kumar[2]

[1]P.G Scholar, E.E.E, JNTUA College of Engineering, Pulivendula, A.P, India

[2]Assistant Professor, EEE, JNTUA College of Engineering, Pulivendula, A.P, India

Abstract: ***Power quality (PQ) is very important to certain consumers. In the future, distribution system operators might decide, to supply their consumers with different Power Quality levels and at different costs. A new device which can fulfill this role is that the OPEN unified power quality conditioner (UPQC), combination of a power-electronic series main unit place in the medium-voltage/low-voltage (LV) substation, in conjunction with power-electronic shunt units connected near to the end users. This device will do general improvement in PQ, reducing the common disturbances for all consumers by using only the series unit. Extra increments in PQ (i.e., mains power interruptions), is given to the consumers who need it (custom power) by the shunt units. Therefore, this new resolution combines associate improvement in PQ for all end users, with reduction in cost for people who need high quality power. For analyzing the proposed solution, a model of a 400-kVA lv grid is taken into account as test network to evaluate the steady-state performance. The results obtained under steady state shows the configuration chosen follows good device performance.***

Keywords: Custom powers, interface devices, OPEN unified power-quality conditioner (UPQC), power quality (PQ).

1. Introduction

In olden days the main concern of consumers of electricity is continuity of supply. Now the consumers demand quality too. A survey [1] report gives the information that industrial customers and main end users did not suffer long outages. Instead, they experienced numerous short duration voltage sags and momentary interruptions. For compensation of these disturbances several solutions are available.

First one is increasing the short circuit level of the distribution network. I.e. revamping all the LV distribution cables or raising the power of the MV/LV substation transformer, in this process, an incoming disturbance from a load (i.e., harmonics) or from a fault in a line is reduced at the point of common coupling (PCC). This solution effectively reduces the depth of the voltage variations, but not protecting the loads against transients and short interruptions. A second solution to compensate any type of disturbance including interruptions is installation [2] of on-line, offline, line interactive and hybrid UPS systems.

Local utility companies or the end users cannot adopt these solutions because they are too expensive relative to the increase in power quality that they produce .Different connection schemes (series or shunt types) are used to realize these devices. The series devices are connected upstream of the protected lines, while the shunt devices are connected in parallel to the sensitive loads. In general, both types of conditioning devices increase the power quality level at the loads, as reported in [3]&[4] for series devices and in [5]for shunt devices.

The unified power quality conditioner (UPQC) consists of a series and a shunt unit, with a common dc link through which power exchange can take place. Its function is to improve the quality levels of the current absorbed at the mains and the load supply voltage [6]. However, these devices do not give guarantee to local distributors to supply different quality demand levels to the final customers, because they improve power quality for all the supplied end users. The installation investments are also quite high relative to the power quality level obtained. A solution that has similar performances and advantages, but also makes cost reduction possible, is the proposed OPEN UPQC.

This new solution, analyzed in [7], [8], starts from the UPQC configuration, removes the common dc connection and splits the shunt unit into several shunted devices. Therefore, the control strategy is different than traditional combined series and shunt converters, but the improvements to load voltage and network current quality are quite similar. Above all, the OPEN UPQC can stabilize load voltage, increase the network power factor, leading to keep load voltage and network current sinusoidal and balanced as well. The transient behavior of a single dynamic voltage restorer device was analyzed and simulated, and its working limits were determined in [4].

The several shunt units are connected near the end users that need high power quality. If a storage system is present, they can exchange *active* power and *nonactive* power with the electrical system. Especially in a grid-connected configuration, *nonactive* power can be exchanged with the mains in order to enhance the series unit performance and extend its working limits.

2. The Open UPQC

Voltage sags have small depth and short durations. More than 95% of voltage sags can be compensated by injecting a voltage of up to 60% of the nominal voltage, with a maximum duration of 30 cycles. For selection of size of OPEN UPQC this information is used. The series unit, can compensate most of the voltage disturbances, it has the same function as the DVR .Each shunt unit is sized in relation to the supplied load power, and can protect its sensitive load against interruptions. The shunt unit's function is similar to that of the UPS output stage [2], but is less expensive because it only has one conversion stage and involves less power loss.

Figure 1 shows Multi wire power layout of the device in a three-phase, four-wire distribution network

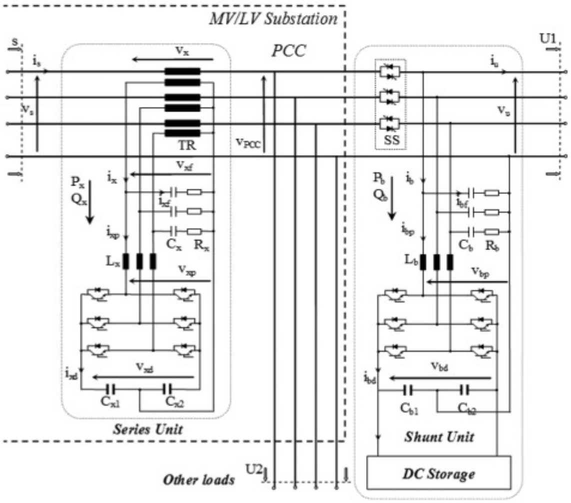

Figure 1: multi wire power diagram of the proposed solution

The series unit Of OUPQC consists of a coupling transformer (TR), with the primary circuit connected in series with the mains line and a secondary one supplying the reversible ac/dc power converter. The output stage of the pulse width modulation (PWM) voltage controlled converter contains passive RC shunt filters, to compensate for the harmonic currents at switching and multiple frequencies. Neglecting the *active* power to compensate the converter losses, the series unit is controlled to act as a purely reactive inductor when the supply voltage is within its operation limits ($0.9V_n \leq Vs \leq 1.1V_n$). The shunt units consist of an ac/dc power converter, similar to the one used in the series unit, connected to an energy storage system and a set of static switches (SS).The shunt unit, depending on the state of the network voltage, can supply either the entire load, or a part of the load.

There are two different modes of OPEN UPQC operation:

- *compensator*: when the PCC voltage is within its operation limits, the SS are closed, the series unit works as a three phase voltage generator and the shunt units work as current generators;
- *Back-up*: when the PCC voltage is outside of its operation limits, the SS are open, decoupling the network and the load-compensator system. Each sensitive load is supplied by its shunt unit, which acts as a sinusoidal voltage generator, using the energy stored in the storage system as an energy source.

3. Open UPQC Performance

To evaluate the compensation capacity of the device in normal operation mode($0.9V_n \leq Vs \leq 1.1V_n$), under steady state conditions, by taking an assumption that the voltages are sinusoidal and are constituted of only the positive sequence component in the different network buses.

The various units of open UPQC requires coordination, this can be achieved by a communication system. In transient analysis, the communication between the series unit and the shunt units cannot be included (the communication could be slow, could be out of order, etc.). Therefore, each unit necessarily works alone.

3.1 Non active Q_b and Q_x Power Exchange

In normal operation mode, the maximum voltage drop in the LV lines of the network must be less than 5% to maintain low power loss. This result allows an improvement of one of the aspects of the supply quality, the stability of the real value of the supply voltage, for all customers. Therefore, the OPEN UPQC works to stabilize the nominal voltage at the PCC. The phasor diagram of the OPEN UPQC is shown in Fig. 2. The series voltage $\bar{V}_X$ has to be in quadrature with the mains current $\bar{I}_S$ to avoid *active* power injections. The value is reported in (1), and the grey areas in Fig. 2 indicate the field of possible $\bar{V}_X$ values.

$$V_X = V_{PCC} \cdot \frac{\sin(|\varphi_{PCC} - \varphi_S|)}{\cos(\varphi_S)} \quad (1)$$

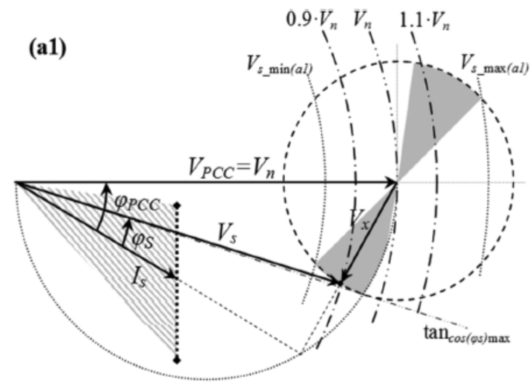

Figure 2 (a): Voltage compensation exchanging only non active power. Case (a) it is possible to obtain power factor equal to 1 in supply section in low voltage situations.

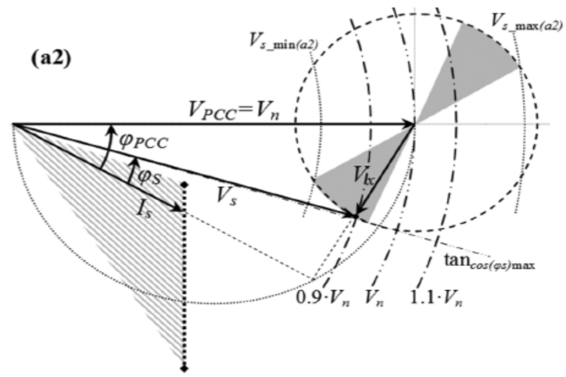

Figure 2(b): Voltage compensation exchanging only non active power. Case (b) the power factor is always less than 1.

The current $\bar{I}_S$ is primarily composed of the current of unprotected Loads $\bar{U}_2$ (whose phase difference with respect to $\bar{V}_{PCC}$ cannot be varied) and the current of protected loads $\bar{U}_1$ (whose phase difference with respect to $\bar{V}_{PCC}$ can be changed by the shunt units) as reported in (2), where $P_{U\,1,2}$ and $Q_{U\,1,2}$ are the active and reactive power of the equivalent load, $\bar{U}_{1,2}$ respectively,P_{losses} and Q_{losses} are the active and reactive power lines losses, respectively, and Q_b is the reactive power injected by all the shunt units.

$$I_S = \frac{P_{U1}+P_{U2}+P_{losses}+j.(Q_{U1}+Q_b+Q_{U2}+Q_{losses})}{V_{PCC}} \quad (2)$$

Therefore, the angle φ_{PCC} can oscillate between the upper and lower limits $\varphi_{PCC\_\max}$ and $\varphi_{PCC\_\min}$, obtained when $Q_b = A_1$ and $Q_b = -A_1$ respectively in the area highlighted in Fig. 3. The angle and the quantities $V_{s-\max}$ and $V_{s-\min}$ can be calculated by the below equations (3), (4) & (5).

$$COS(\varphi_{PCC}) = \frac{(P_{U1}+P_{U2}+P_{losses})}{\sqrt{(P_{U1}+P_{U2}+P_{losses})^2+(Q_{U1}+Q_b+Q_{U2+}Q_{losses})^2}}$$

$$V_{s-\min} = \sqrt{V^2{}_{s-\max}+V^2{}_{pcc}-2V_{pcc}.V_{x-\max}.Sin(\varphi_{pcc-\max})}$$

$$V_{s-\max} = \sqrt{V^2{}_{s-\max}+V^2{}_{pcc}+2V_{pcc}.V_{x-\max}.Sin(\varphi_{pcc-\max})}$$

Assuming that $V_{s-\max}+V_{s-\min} \approx 2.V_{PCC}$ the amplitude $V_{s-\max}-V_{s-\min}$ can be obtained with (6) below

$$V_{s-\max}-V_{s-\min} \approx 2.V_{x-\max}\sin(\varphi_{PCC-\max}). \quad (6)$$

The compensating range amplitude $V_{s-\max}-V_{s-\min}$ depends on the $V_{x\_\max}$ value that the series unit can inject, and on the *non active* power Q_b .The *nonactive* power is exchanged by the shunt units (length of the black dotted line ,proportional to the loads U_1 apparent power) and to the power factors of the equivalent loads U_1 and U_2.

4. Control Strategy

In normal operation mode ($0.9V_n \le Vs \le 1.1V_n$), under steady state conditions, the control technique of device can be described below. In order to compensate for the voltages in normal operation, the strategy that maximizes the power factor $\cos(\varphi_s)$ (corresponding to the current I_S minimization) can be chosen. With this choice, it is possible to minimize the apparent power required by the mains. The mains current I_S is reported in (2), and the compensated voltage V_{PCC} is

$$V_{PCC} = V_S - V_X \quad (7)$$

Neglecting power losses and considering that the voltage V_X has to be in quadrature with the current I_S, it is possible to write the following relation:

$$I_s = \frac{P_{u1}+P_{u2}+j.(Q_{u1}+Q_{u2}+Q_{u2})}{\overline{V}_s - j.x.\overline{I}_s} \quad (8)$$

Where x is the equivalent reactance of the series unit, giving a voltage proportional to I_S. Due to the nonlinearity of the problem Solving (7) and (8) is not mathematically easy, and implementing them into a controller is not useful. It is more convenient to implement two PI controllers, one to evaluate the voltage V_X of the series unit, and another to evaluate a signal K_{Qb} related to the *nonactive* power Q_b that all of the shunt units have to inject.

The conditions under which the series unit can exchange only *nonactive* power can be obtained by applying the Park transform to the three phase currents I_{s-a} ,I_{s-b} and I_{s-c} , and calculating the two components I_{s-d} and I_{s-q} in a rotating reference frame, as reported in [9]

$$\begin{bmatrix} I_{S-d} \\ I_{S-q} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} COS(\theta) & COS(\theta-\frac{2}{3}\pi) & COS(\theta+\frac{2}{3}\pi) \\ -Sin(\theta) & Sin(\theta-\frac{2}{3}\pi) & Sin(\theta+\frac{2}{3}\pi) \end{bmatrix} \begin{bmatrix} I_{s-a} \\ I_{s-b} \\ I_{s-c} \end{bmatrix} \quad (9)$$

Where the angle θ is equal to $2.\pi.f.t$ And f is the mains frequency. Consequently, the d-q components of the injected voltage V_X have to be proportional to the q-d components of the current I_S as follows:

$$V_{x-d} = -kV_x.I_{s-q}$$

$$V_{x-q} = kV_x.I_{s-q} \quad (10)$$

For the constant k_{vx} to be independent of the load conditions, the previous expressions must be normalized with respect to the load current module.

$$V_{x-d} = -kV_x.\frac{I_{s-q}}{\sqrt{I^2_{s-d}+I^2_{s-q}}}$$

$$V_{x-q} = kV_x.\frac{I_{s-d}}{\sqrt{I^2_{s-d}+I^2_{s-q}}}. \quad (11)$$

The constant k_{vx} is obtained by a PI controller that keeps the voltage at the series unit output V_{PCC} equal to the rated value V_{ref} as reported in the block diagram of Fig 3.

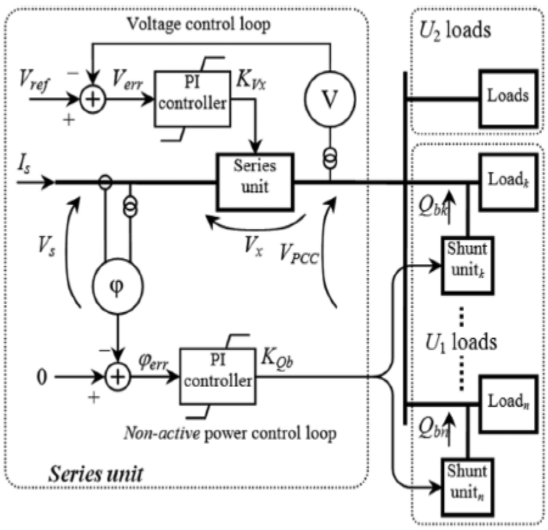

Figure 3: Voltage control loop of series unit and non active power control loop of shunt units in the OPEN UPQC system.

The angle φ_S between the voltage V_S and the current I_S can be minimized by the use of second control loop placed downstream of the MV/LV transformer, in order to maximize the power factor absorption in the s section. In this case, the PI controller produces a signal K_{Qb} , which varies from 0 to 1, and is equal to the ratio between the desired *nonactive* power injectable by the shunt units and the maximum injectable *nonactive* power. The communication system sends this signal to all the shunt units. Thus, the injected *nonactive* power of the kth shunt unit Q_{bk} is equal to

$Q_{bk} = k_{Qb} . A_k$ (12) Where A_k is the unit's rated power.

The total nonactive power injected by all the shunt units is,

$$Q_b = \sum_{k=1}^{n} Q_{bk} \quad (13)$$

To enhance the entire system's performance, the power losses and the voltage drops in the LV lines generally must increase. However, if the power factor at the PCC is kept high ($\geq$ 0.8), these increments are negligible. Moreover, this increment can be reduced by sending a different signal k_{Qbk} to each shunt unit. This allows the closest shunt units to be used to inject more *nonactive* power, avoiding useless *nonactive* power flows.

5. Test Network and Evaluation of Operation Limits

To validate the OPEN UPQC system a simplified 400-KVA LV grid is shown in below figure 4. The protected loads are grouped into the equivalent load U_1 so all of the shunt units are represented by means of an equivalent unit. In the same way, all of the unprotected loads are grouped in the equivalent load U_2 shown below.

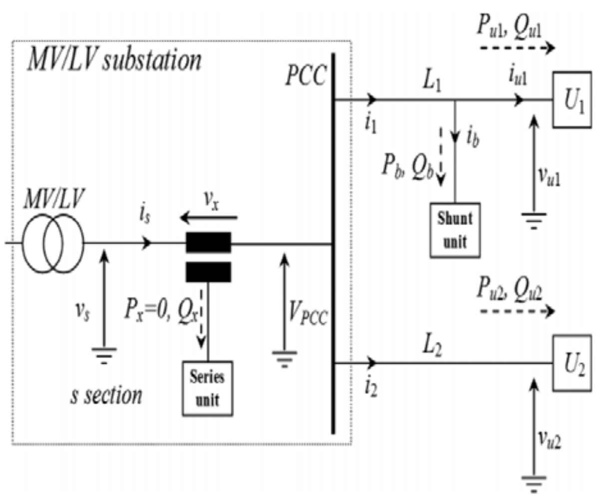

Figure 4: System compensation structure

Three-phase MV/LV transformer parameters used for the simulations are reported in Table I.

Table 1: MV/LV Transformer Parameters

Power (KVA)	K	R(mΩ)	X(mΩ)	P_{CC}(%)	P_{Fe}(%)
400	20/0.4	3.6	15.6	0.9	0.19

In this study, all of the converters are represented as ideal controlled voltage or current sources. Moreover, the series unit is not equipped with a storage system. For these reasons, the OPEN UPQC limits are evaluated mainly in the *normal operation* mode in the following. Therefore, the series unit cannot exchange *active* power with the mains.

The following figures and tables report the power factor cos (φ_s) and the mains current I_s in the section as functions of the network voltage V_s . Each diagram is represented for a fixed load power factor U_1 and U_2 and is parametric in α . This parameter α indicates the ratio between the apparent powers of the total loads of shunt units $\overline{A}_{U1}$ and the total apparent power of loads A_{ref} ,

$$\alpha = \frac{\left|\overline{A}_{U1}\right|}{\left|\overline{A}_{U1} + \overline{A}_{U2}\right|} = \frac{A_{U1}}{A_{ref}}. \quad (14)$$

With a fixed A_{U1} , and therefore fixed α , it is possible to calculate A_{U2} as a function of the power factors of the loads cos (φ_{U1}) and cos (φ_{U2})

$$\frac{A_{U2}}{A_{ref}} = \sqrt{1-\alpha^2.\{1-[\cos(\varphi_1-\varphi_2)]^2\}} - \alpha.\cos(\varphi_1-\varphi_2). \quad (15)$$

The reference current is expressed in per unit (p.u.), as the ratio between the power reference and the voltage reference. Since the network cables are correctly designed and their parameters are constant, the voltage drop variation when the OPEN UPQC is present can be neglected under maximum load conditions when the load power factor is equal to 0.9 and it is connected at the end of the line.

The operation limits reported in Figs.5 and 6, which allow the voltage V_{PCC} to be fixed at the nominal value, were obtained by assuming the above hypothesis and that the maximum injectable voltage by the series unit is equal to 0.6 p.u. The following results for the proposed solution were obtained by converting the vector diagrams of Fig.2 into geometrical equations. In the following, the maximum *nonactive* power injected by all the shunt units Q_b can reach the apparent power $\pm A_{U1}$. In this case, if the control strategy can keep the voltage V_{PCC} equal to the nominal value, then these relations have to be true.

$$\cos(\varphi_s) = \frac{V_{PCC}}{V_S}.\cos(\varphi_{PCC}) \quad (16)$$

$$\frac{I_S}{I_{ref}} = [(\alpha.\cos(\varphi_1) + \frac{A_{U2}}{A_{ref}}.\cos(\varphi_2))^2$$

$$+ (\alpha.\sin(\varphi_1) + Q_b + \frac{A_{U2}}{A_{ref}}.\sin(\varphi_2))^2]^{\frac{1}{2}}. \quad (17)$$

The operation limits given by (16) and (17) were obtained by using equation (3) and (15).

The figures 5 and 6 shown below reveal that:

Case 1: The OPEN UPQC is well-adapted when the power factor of the load is low. Fig. 5 shows the interval that can be compensated by exchanging only *non active* power when the power factor of the load U_2 is equal to 0.8. In this case, the OPEN UPQC produces excellent voltage stabilization, especially when the parameter α is greater than 0.4; Case 2: The OPEN UPQC is not well-adapted when the power factor of the load U_2 is high. Fig. 6 shows the interval that can be compensated by exchanging only *nonactive* power when the power factor of the load U_2 is equal to 1. In this case, the OPEN UPQC does not produce good voltage stabilization, because it is too limited. It is possible to obtain voltage stabilization in normal operation mode range (between 0.9 p.u and 1.1 p.u) only with a high α value.

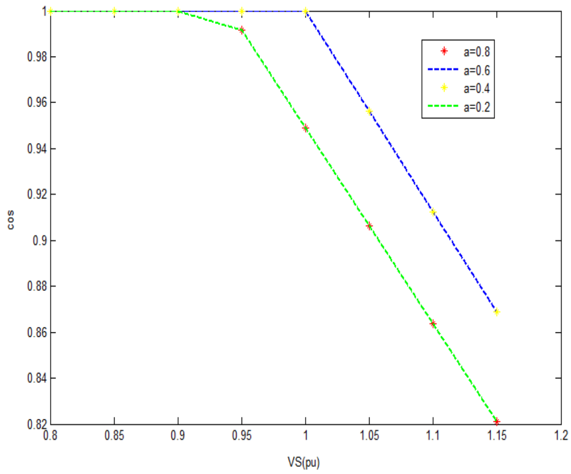

Figure 5 (a)

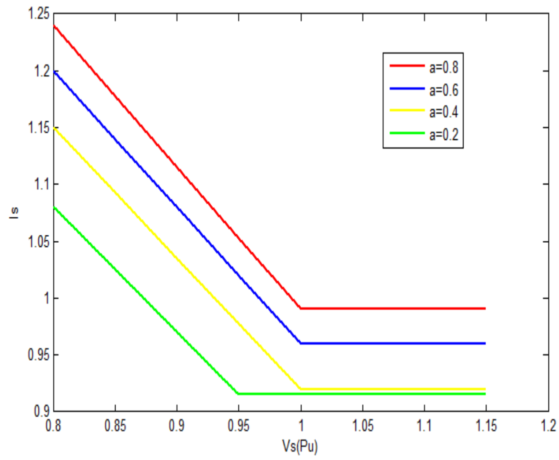

Figure 5 (b)

Fig 5(a) & 5(b) - Power factors of the system and maximum line currents in case 1, for different α values. The maximum voltage of the series unit is equal to 0.6 p.u.

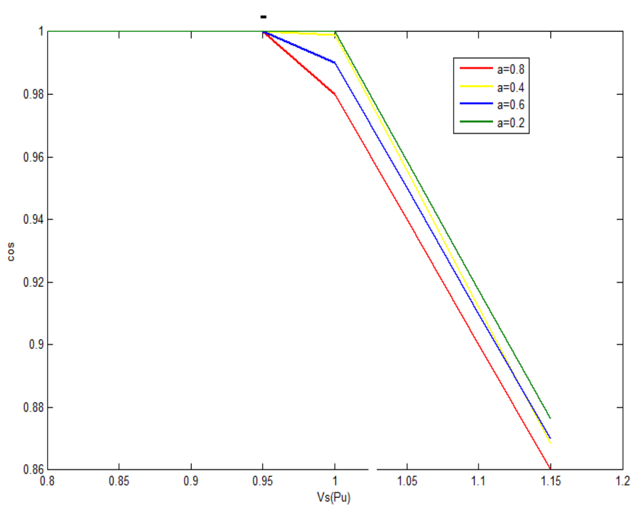

Figure 6 (a)

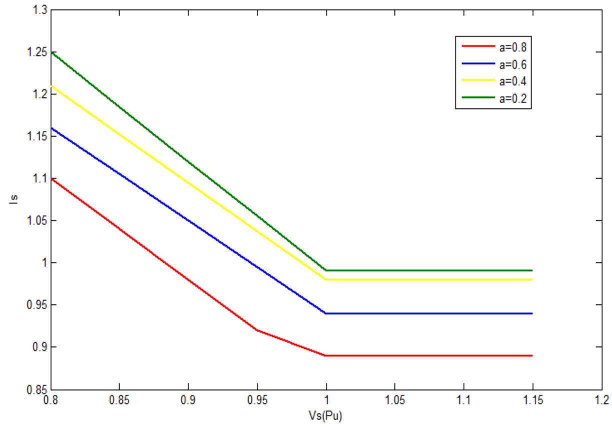

Figure 6 (b)

Fig 6(a) & 6(b) Power factors of system and maximum line currents in case 2 for different α values. The maximum voltage of series unit is equal to 0.6 p.u. From Figs.5 and 6, it is possible to estimate the power of the series unit, given the maximum I_S current value. This value is equal to the product between the maximum injectable voltage (equal to 0.6 p.u.) and the maximum line current (equal to 1.1 p.u. when $\alpha = 0.8$ and V_S =0.9 p.u.as shown in Fig. 6). Therefore, with slight over-sizing of the series unit, good stabilization of the mains voltage is possible. When the power factor of load U_2 is between 0.9 and 1, and the mains voltage is inside of the contractual limits (*normal operation*).

6. Cost Evaluation

Analysis of the 400-kVA LV distribution network is taken to evaluate the costs of power quality improvement and the economic convenience of the proposed solution. It was supposed that the line L_1 represents an equivalent line in which all of the sensitive loads U_1 that make up the OPEN UPQC are connected, while the line L_2 represents an equivalent line that supplies only the non sensitive loads U_2 . Therefore, each load that belongs to the set U_1needs to be protected against disturbances and network interruptions, while the ones that belong to set U_2 only require general improvement of the power quality. Several solutions are available for compensating each load U_1 they are

- Installation of a UPS for each end user. In this case, it is not possible to improve the power quality of the distribution network. However, it is possible to compensate for all voltage disturbances for the end users;
- Revamping of all of the LV distribution cables. In this case, it is not possible to compensate for all voltage disturbances;
- Installation of an OPEN UPQC. In this case, it is possible to compensate for most of the voltage disturbances.

The last solution consists of the installation of a series unit sized for 66% of the total power loads supplied (264 kVA), while each shunt unit has an assumed size of 5 kVA. Moreover, each UPS is assumed to have the same power, and the input stage of each UPS is composed of PFC rectifiers. The storage systems cost for UPS and OPEN UPQC solutions in this analysis is not considered, because it primarily depends on the technologies and autonomies required. To compensate most of the disturbances in the whole network, installing the series unit only is a better solution than revamping all of the LV distribution system. To compensate for the loads U_1 , it is necessary to install a UPS or a shunt unit close to them, which increases the total cost as a function of their power. UPS's are good solution if only a few sensitive loads are present. However, if it is necessary to improve the power quality of the whole network, they become too expensive to use. They can only be more convenient than the proposed OPEN UPQC if the total power of the sensitive loads U_1 is lower than about 80 kVA (20% of the total load) when, and only when, it is not necessary to increase the PQ of the network.

7. Conclusion

The OPEN UPQC apparatus is a good compensation system if wide installation of shunt units is needed. An increase in the percentage α of the protected load enhances the voltage stabilization interval over which the OPEN UPQC can significantly improve the power quality, especially if the load U_2 power factor takes a high value. If the power factor of load U_2 is less than one, the power factor in section increases, to avoid *nonactive* power absorption from the mains. For low values of the α parameter, the OPEN UPQC becomes expensive if there are few shunt units. In this case, it is better to install other compensation device typologies (as UPS, UPQC, etc.) near the sensitive loads, and a *nonactive* compensator system near the nonsensitive loads if necessary.

It is possible to conclude that installation of the series unit is a cost-effective way for distributors to improve the power quality level in the distribution networks in order to achieve the standards imposed by the authorities. Compensation improvement for the sensitive end users U_1 can be achieved by installing a shunt unit near them, instead of the more expensive UPS device. The OPEN UPQC working conditions are reported in Table II. The OPEN UPQC study is still under investigation.

Table 2: OPEN UPQC Units Actions

Voltage	OPEN UPQC action		LOAD
	Series unit	Shunt unit	
Interruption $V_s<0.01 \cdot V_n$	no action	P_b and Q_b injection	U_1 supplied U_2 unsupplied
Deep voltage sags $0.01 \cdot V_n \leq V_s < 0.4 \cdot V_n$	no action	P_b and Q_b injection	U_1 supplied U_2 unsupplied
Voltage sags $0.4 \cdot V_n \leq V_s < 0.9 \cdot V_n$	P_x^1 and Q_x injection	Q_b injection	U_1 supplied U_2 supplied
Voltage fluctuation $0.9 \cdot V_n \leq V_s \leq 1.1 \cdot V_n$	Q_x injection	Q_b injection	U_1 supplied U_2 supplied

8. Future Scope

Number of installations of Custom Power Devices is increasing in the world. Increasing competitiveness and new utility regulations force the industrial consumers towards installation of Custom Power Devices. Mostly shunt active power filter installations are reported in the market and research on Custom Power Devices is expected to grow in the near future.

References

[1] D. M. Divan, W. E. Brumsickle, G. A. Luckjiff, J. W. Freeborg, and R. L.Hayes, "Realizing a nation-wide power quality and reliability monitoring system," 2003. [Online]

[2] J. M. Guerrero, L. Garcia de Vicuna, and J. Uceda, "Uninterruptible power supply systems provide protection," *IEEE Ind. Electron. Mag.*, vol.1, no. 1, pp. 28-38, spring, 2007.

[3] D. M. Vilathgamuwa, H. M. Wijekoon, and S. S. Choi, "A novel technique to compensate voltage sags in multiline distribution system— the interline dynamic voltage restorer," *IEEE Trans. Ind. Electron.*, vol.53, no. 5, pp. 1603-1611, Oct. 06.

[4] A. Ghosh and G. Ledwich, "Compensation of distribution system voltage using DVR," *IEEE Trans. Power Del.*, vol. 17, no. 4, pp. 1030- 1036, Oct. 2002.

[5] B. Singh, A. Adya, A. P. Mittal, and J. R. P. Gupta, "Analysis, simulation and control of DSTATCOM in three-phase, four-wire isolated distribution systems," presented at the IEEE Power India Conf., New Delhi, India, and Apr. 10-12, 2006.

[6] G. Jianjun, X. Dianguo, L. Hankui, and G. Maozhong, "Unified power quality conditioner (UPQC): The principle, control and application," in *Proc. Power Conversion Conf. (PCC)*, Osaka, Japan, 2002, vol. 1, pp. 80-85.

[7] R. Faranda, E. Tironi, I. Valadè, and D. Zaninelli, "Power quality improvement using series electronic reactor and shunt power conditioner," in *Proc. Int. Symp. and Exhib. Electric Power Engineering at the Be-ginning of the Third Millennium*, Capri, Italy, May 12-18, 2000.

[8] M. Brenna, R. Faranda, and E. Tironi, "OPEN UPQC able to improve power quality of network and loads," in *Proc. Int. Congr. Electricity Distribution*, Buenos Aires, Argentina, Nov. 27-29, 2006.

[9] R. Faranda, F. Castelli Dezza, I. Mazzucco, P. Redi, and E. Tironi,"An interface converter for DG/storage system able to improve power quality of the load," presented at the IEEE Power Eng. Soc., Montreal, QC, Canada, Jun. 18-22, 2006.

[10] K.R. Padiyar "Facts Controllers in Power Transmission and Distribution", New Ag International (P) Limited, Publishers

Author Profile

P. Kondala Rao is pursing M.tech in Electrical Power Engineering from JNTUA College of Engineering Pulivendula. He is presently working on his project under the guidance of Assistant Professor K.Vimala Kumar.

K. Vimala Kumar received the Master of Technology degree in Electrical Engineering from Jawaharlal Nehru college of Hyderabad, India in 2008. He is a research student of Jawaharlal Nehru Technological Ananatapur. Currently, he is working as Assistant Professor in the department of Electrical and Electronics Engineering, J.N.T.U.A College of Engineering,

Pulivendula-516390, and Andhra Pradesh, India. His interested areas are power system deregulation, Power system operation and control, power system design and dynamic load modeling.