IMPROVING POWER QUALITY BY USING MC-UPQC

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ABSTRACT - In order to meet Power Quality (PQ) standard limits, it may be necessary to include some sort of compensation. Modern solutions can be found in the form of active rectification or active filtering. A shunt active power filter is suitable for the suppression of negative load influence on the supply network, but if there are supply voltage imperfections, a series active power filter may be needed to provide full compensation. In recent years, solutions based on Flexible AC Transmission Systems (FACTS) have appeared. The application of FACTS concepts in distribution systems has resulted in a new generation of compensating devices. A Unified Power Quality Conditioner (UPQC) is the extension of the Unified Power-Flow Controller (UPFC) concept at the distribution level. It consists of combined series and shunt converters for simultaneous compensation of voltage and current imperfections in a supply feeder.

An Interline Power-Flow Controller (IPFC) consists of two series Voltage-source Converters (VSC) whose dc capacitors are coupled. This allows active power to circulate between the VSCs. With this configuration, two lines can be controlled simultaneously to optimize the network utilization. An Interline Unified Power-Quality Conditioner (IUPQC), which is the extension of the IPFC concept at the distribution level. The IUPQC consists of one series and one shunt converters. It is connected between two feeders to regulate the bus voltage of one of the feeders, while regulating the voltage across a sensitive load in the other feeder. In this configuration, the voltage regulation in one of the feeders is performed by the shunt-VSC. However, since the source impedance is very low, a high amount of current would be needed to boost the bus voltage in case of a voltage sag/swell which is not feasible. It also has low dynamic performance because the dc-link capacitor voltage is not regulated.

This project presents a new unified power-quality conditioning system (MC-UPQC), capable of simultaneous compensation for voltage and current in multi-bus/multi-feeder systems. By using one shunt voltage-source converter (shunt VSC) and two or more series VSCs the configuration is made. The system can be applied to adjacent feeders to compensate for supply-voltage and load current imperfections on the main feeder and full compensation of supply voltage imperfections on the other feeders. The configuration will be designed as all converters are connected back to back on the dc side and share a common dc-link capacitor. Therefore, power can be transferred from one feeder to adjacent feeders to compensate for sag/swell and interruption. The proposed topology can be used for simultaneous compensation of voltage and current imperfections in both feeders by sharing power compensation capabilities between two adjacent feeders which are not connected. The system is also capable of compensating for interruptions without the need for a battery storage system and consequently without storage capacity limitations. By the simulation the performance of MC-UPQC as well as the adopted control algorithm will be illustrated.

1. INTRODUCTION

With the ultimate objective to meet PQ standard limits, it may be critical to join a kind of pay. Present day courses of action can be found as dynamic correction or dynamic separating. A shunt dynamic power channel is sensible for the concealment of negative load impact on the supply arrange, anyway if there are supply voltage deserts, an arrangement dynamic power channel may be relied upon to give full remuneration. Starting late, courses of action dependent on Flexible AC Transmission Systems (FACTS) have appeared. The use of FACTS thoughts in circulation frameworks has achieved another age of reimbursing gadgets. A Unified Power Quality Conditioner (UPQC) is the extension of the Unified Power-Flow Controller (UPFC) thought at the appropriation level. It includes joined arrangement and shunt converters for synchronous remuneration of voltage and current imperfections in a supply feeder. Starting late, multiconverter FACTS gadgets, for example, an Interline Power-Flow Controller (IPFC) and the Generalized Unified Power-Flow Controller (GUPFC) are introduced. The purpose of these gadgets is to control the power stream of multiline or a sub mastermind instead of control the power stream of a solitary line by, for instance, an UPFC.

In this undertaking, another design of an UPQC called the Multiconverter Unified Power-Quality Conditioner (MC-UPQC) is shown. The framework is connected by incorporating an arrangement VSC in a neighboring feeder. The proposed topology can be used for synchronous remuneration of voltage and current defects in the two feeders by sharing force pay limits between two abutting feeders which are not related. The framework is moreover prepared for compensating for intrusions without the prerequisite for a battery amassing framework and consequently without limit restrain limitations.

2. POWER QUALITY

2.1 INTRODUCTION

The term Power Quality means unmistakable things to different people. Power quality is the nature of the electric power provided to electrical hardware. Poor power quality can result in maloperation of the gear the electric utility may describe control quality as immovable quality and express that the framework is 99.95% reliable.

Ideally the power would be provided as a sine wave with the abundancy and recurrence given by national norms (by virtue of mains) or framework points of interest (by virtue of a power feed not specifically joined to the mains) with an impedance of zero ohms at all frequencies.

No honest to goodness control feed will ever meet this ideal. It can go not right from it in the going with courses (among others): Varieties in the zenith or rms voltage (both these figures are fundamental to different sorts of gear) when the rms voltage outperforms the apparent voltage by a particular edge, a surge is conveyed. A dive is the opposite condition: The rms voltage is underneath the apparent voltage by a particular edge.

- Sag happens when the low voltage persists over a more expanded day and age.
- Variations in the recurrence.
- Variations in the wave shape – regularly depicted as music.
- Non zero high recurrence impedance (if the machine requests a great deal of current or stops requesting it out of the blue there will be a dunk or spike in the voltage due to the inductances in the power supply line).
- Rapid spikes and dunks and longer term assortments in voltage (for the most part caused by the participation of other hardware with line impedance).

2.2 POWER QUALITY IN POWER DISTRIBUTION SYSTEMS

A substantial part of the more basic general gauges describe control quality as the physical attributes of the electrical supply gave under ordinary working conditions that don't upset or trouble the customer's techniques. Along these lines, a power quality issue exists if any voltage, current or recurrence deviation results in a mistake or in a frightful task of customer's hardware. Be that as it may, see that the nature of intensity supply gathers basically voltage quality and supply steadfast quality. A voltage quality issue relates to any failure of hardware on account of deviations of the line voltage from its apparent attributes, and the supply unflinching quality is portrayed by its adequacy (ability to supply the heap), security (ability to withstand sudden agitating impacts, for example, framework deficiencies) and availability (focusing especially on long intrusions). Power quality issues are regular in the dominant part of business, current and utility frameworks. Basic marvels, for example, lightning are the most constant explanation behind power quality issues. Exchanging marvels achieving oscillatory vagrants in the electrical supply, for example when capacitors are exchanged, moreover contribute extensively to control quality aggravations. Moreover, the relationship of high power non-straight loads adds to the age of current and voltage consonant portions. Between the assorted voltage agitating impacts that can be conveyed, the most tremendous and fundamental power quality issues are voltage balances due to the high mild misfortunes that can be created. Here and now voltage drops (records) can trip electrical drives or more delicate gear, inciting extreme interferences of age. For each one of these reasons, from the client viewpoint, control quality issues will transform into an unyieldingly basic factor to consider with the true objective to satisfy incredible productivity. On the other hand, for the electrical supply industry, the nature of intensity passed on will be one of the distinctive elements for ensuring customer steadfastness in this amazingly engaged and deregulated publicize. To address the necessities of imperativeness buyers trying to upgrade productivity through the decrease of intensity quality related process stoppages and essentialness providers endeavoring to enhance working advantages while keeping customers content with supply quality, creative innovation gives the best approach to useful power quality improvements courses of action. In any case, with the distinctive power quality game plans available, the verifiable request for a client or utility standing up to a particular power quality issue is which gear gives the better arrangement.

Power quality contrasts on a very basic level beginning with one district then onto the following. A couple of countries have especially stable power networks while others are to an incredible degree short on breaking point.

Power aggravations are caused by the age, dissemination and use of intensity, and lightning. A control agitating impact can be described as unwanted excess imperativeness that is shown to the heap.

3. INTRODUCTION

Versatile AC Transmission Systems, called FACTS, got in the continuous years an extraordinary term for higher controllability in power frameworks by strategies for power electronic gadgets. A couple of FACTS-gadgets have been exhibited for various

applications around the globe. Different new sorts of gadgets are in the period of being exhibited eventually.
In most of the applications the controllability is used to keep up a key separation from cost genuine or scene requiring developments of intensity frameworks, for instance like updates or increments of substations and electrical cables. Surenesses gadgets give a better change than fluctuating operational conditions and improve the usage of existing foundations. The basic uses of FACTS-gadgets are:

- Power stream control,
- Increase of transmission limit,
- Voltage control,
- Reactive power pay,
- Stability enhancement,
- Power quality enhancement,
- Power molding,
- Flicker relief,
- Interconnection of feasible and dispersed age and reserves.

The right segment of FACTS-devices contains further developed technology of voltage source converters based today primarily on Insulated Gate Bipolar Transistors (IGBT) or Insulated Gate Commutated Thyristors (IGCT). Voltage Source Converters give a free controllable voltage in extent and phase because of a pulse width modulation of the IGBTs or IGCTs. High modulation frequencies permit to get low harmonics in the output signal and even to remunerate aggravations originating from the system.
The disservice is that with an expanding switching frequency, the losses are expanding also. Therefore exceptional plans of the converters are required to repay this.

4. UNIFIED POWER QUALITY CONDITIONER

The arrangement of both DSTATCOM and DVR can control the power quality of the source current and the load bus voltage. Furthermore, if the DVR and STATCOM are associated on the DC side, the DC bus voltage can be directed by the shunt associated DSTATCOM while the DVR supplies the expected vitality to the load if there should arise an occurrence of the transient unsettling influences in source voltage. The configuration of such a device (named as Unified Power Quality Conditioner (UPQC)) is shown in Fig. This is a flexible device like an UPFC. However, the control targets of an UPQC are very not quite the same as that of an UPFC.

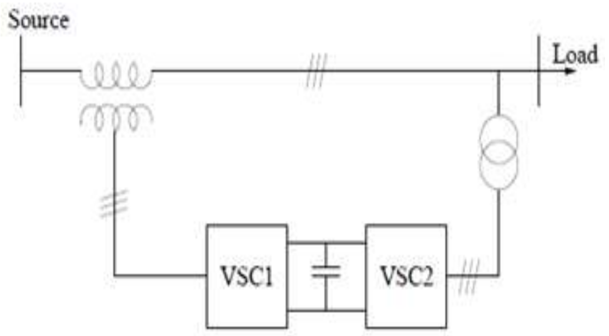


Fig 4.1 UPQC scheme

5. MODELLING OF PROPOSED MC-UPQC SYSTEM

5.1 INTRODUCTION

The single-line diagram of a distribution system with an MC-UPQC is shown in Fig5.1

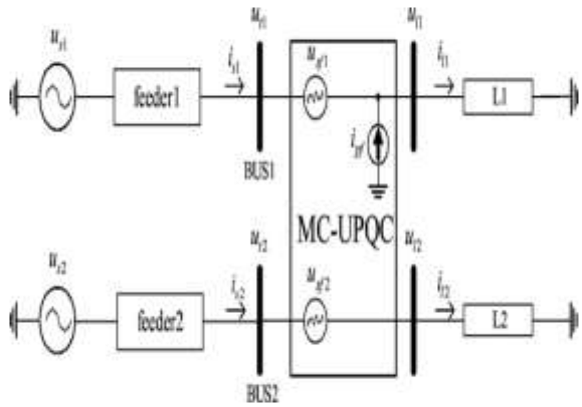


Fig. 5.1 Single-line diagram of a distribution system with an MC-UPQC.

As shown in figure.5.1, two feeders associated with two distinct substations supply the loads L1 and L2. The MC-UPQC is associated with two busses BUS1 and BUS2 with voltages of ut1 and ut2, individually. The shunt some portion of the MC-UPQC is additionally associated with load L1 with a current of il1. Supply voltages are meant by us1 and us2 while load voltages are ul1 and ul2 finally, feeder currents are signified by is1 and is2 load currents are il1 and il2 Bus voltages ut1 and ut2 are twisted and might be subjected to hang/swell. The load L1 is a nonlinear/delicate load which needs an unadulterated sinusoidal voltage for legitimate operation while its current is non-sinusoidal and contains harmonics. The load L2 is a touchy/basic load which needs an absolutely sinusoidal voltage and must be completely ensured against distortion, droop/swell, and interruption. These sorts of loads basically incorporate generation ventures and basic specialist co-ops, such as medicinal focuses, airplane terminals, or broadcasting focuses where voltage interruption can result in extreme conservative losses or human harms.

5.2 CONTROL STRATEGY

As shown in Fig.5.2, the MC-UPQC comprises of two series VSCs and one shunt VSC which are controlled freely. The switching control strategy for series VSCs and the shunt VSC are chosen to be sinusoidal pulse width-modulation (SPWM) voltage control and hysteresis current control, separately. Points of interest of the control algorithm, which are based on the d– q method, will be talked about later.

Shunt-VSC: Functions of the shunt-VSC are:
1) To adjust for the reactive segment of load L1 current;
2) To adjust for the harmonic segments of load L1 current;
3) To manage the voltage of the common dc-interface capacitor.

Fig.5.4 shows the control square chart for the shunt VSC.

The deliberate load current (i_(l_dq0)) is changed into the synchronous dq0 reference outline by utilizing

$$i_{l\_dq0} = T_{abc}^{dq0} i_{l\_abc}. \quad \dots \quad 5.1$$

$$T_{abc}^{dq0} = \frac{2}{3}\begin{bmatrix} \cos(\omega t) & \cos(\omega t - 120^0) & \cos(\omega t + 120^0) \\ -\sin(\omega t) & -\sin(\omega t - 120^0) & -\sin(\omega t + 120^0) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \quad \dots \quad 5.2$$

Where the transformation matrix is shown in eq (5.2), by this transform, the fundamental positive-sequence component, which is transformed into dc quantities in the d and q axes, can be easily extracted by low-pass filters (LPFs). Also, all harmonic components are transformed into ac quantities with a fundamental frequency shift

$$i_{l\_d} = \bar{i}_{l\_d} + \tilde{i}_{l\_d} \quad \dots \quad 5.3$$

$$i_{l\_q} = \bar{i}_{l\_q} + \tilde{i}_{l\_q} \quad \dots \quad 5.4$$

Where, i_{l_d}, i_{l_q} are d-q components of load current, $\bar{i}_{l\_d}$, $\bar{i}_{l\_q}$ are dc components, and $\tilde{i}_{l\_d}$, $\tilde{i}_{l\_q}$ are the ac components of i_{l_d}, i_{l_q}. If i_s is the feeder current and i_{pf} is the shunt VSC current and knowing $i_s = i_l - i_{pf}$, then d–q components of the shunt VSC reference current are defined as follows:

$$i_{pf\_d}^{ref} = \tilde{i}_{l\_d} \quad \dots \quad 5.5$$

$$i_{pf\_q}^{ref} = i_{l\_q} \quad \dots \quad 5.6$$

Consequently, the d–q components of the feeder current are

$$i_{s\_d} = \tilde{i}_{l\_d} \quad .. \quad 5.7$$

$$i_{s\_q} = 0 \quad \dots \quad 5.8$$

This means that there are no harmonic and reactive components in the feeder current. Switching losses cause the dc-link capacitor voltage to decrease. Other disturbances, such as the sudden variation of load, can also affect the dc link the output of the PI controller ($ie., \Delta i_{dc}$) is added to the d component of the shunt-VSC reference current to form a new reference current as follows:

$$\begin{cases} i_{pf\_d}^{ref} = \tilde{i}_{l\_d} + \Delta i_{dc} \\ i_{pf\_q}^{ref} = i_{l\_q} \end{cases} \quad \dots \quad 5.9$$

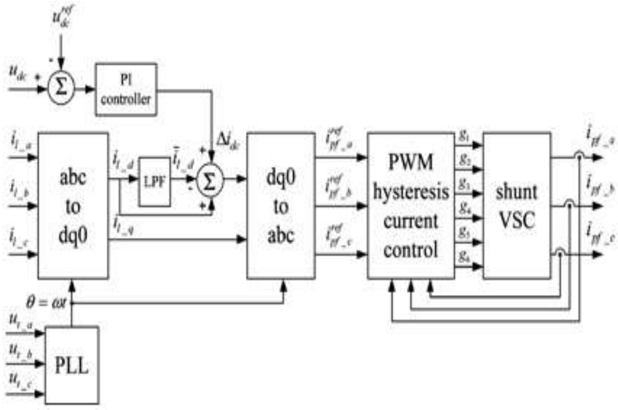


Fig 5.4. Control block diagram of the shunt VSC

As shown in Fig. 5.4, the reference current in eq(5.9) is then changed once more into the abc reference outline.

By utilizing PWM hysteresis current control, the output-repaying currents in each phase are gotten.

i_(pf_abc)^ref=T_dq0^abc i_(pf_dq0)^ref;(T_dq0^abc= 〖T_abc^dq0〗^(- 1)) … 5.10

. With the end goal to manage the dc-connect capacitor voltage, a proportional– indispensable (PI) controller is utilized as shown in Fig 5.4. The input of the PI controller is the blunder between the actual capacitor voltage u_dc and its reference esteem (u_dc^ref).

Series-VSC: Functions of the series VSCs in each feeder are:

1. To relieve voltage list and swell;
2. To make up for voltage distortions, such as harmonics;
3. To make up for interruptions (in Feeder2 as it were).

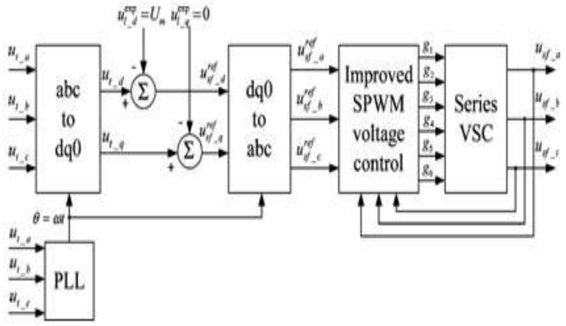


Fig 5.5. Control block diagram of the series VSC

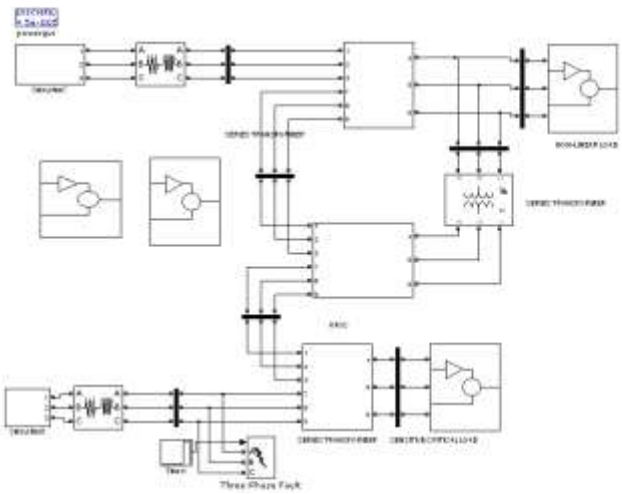
The control square chart of each series VSC is shown in Fig 5.5. The bus voltage (u_(t-abc)) is distinguished and then changed into the synchronous dq0 reference outline utilizing

The remunerating reference voltage in the synchronous dq0 reference outline u_(sf_dq0)^ref is characterized. This implies u_(t1p_d) in eq(5.12) should be kept up at um while all other undesirable parts must be disposed of. The repaying reference voltage is then changed once again into the abc reference outline. By utilizing an enhanced SPWM voltage control technique the output compensation voltage of the series VSC can be acquired.

6. MATLAB DESIGN OF MC-UPQC STUDY AND RESULTS

6.1 INTRODUCTION

The proposed MC-UPQC and its control schemes have been tried through broad contextual analysis



reenactment utilizing MATLAB. In this segment, reproduction results are exhibited, and the execution of the proposed MC-UPQC system is shown.

Fig 6.1 Simulation diagram of MC-UPQC for showing results under distortion, sag/swell, upstream fault and load change

6.2 MATLAB DESIGN OF MC-UPQC STUDY AND RESULTS

6.2.1 Distortion and Sag/Swell on the Bus Voltage

Give us a chance to consider that the power system in comprises of two three-phase three-wire 380(v) (rms, L-L), 50-Hz utilities. The BUS1 voltage contains the seventh-arrange harmonic with an estimation of 22%, and the BUS2 voltage contains the fifth request harmonic with an estimation of 35%. The BUS1 voltage contains 25% list among s and 20% swell betweens. The BUS2 voltage contains 35% list betweens and 30% swell betweens. The nonlinear/touchy load L1 is a three-phase rectifier load which supplies a RC load of 10 and 30 F. At long last, the basic load L2 contains a fair RL load of 10 and 100 mH.

The MC– UPQC is switched on at 0.02 s. The BUS1 voltage, the comparing compensation voltage infused by VSC1, and at long last load L1 voltage are shown in Fig. 6.2 In all figures, just the phase waveform is shown for effortlessness.

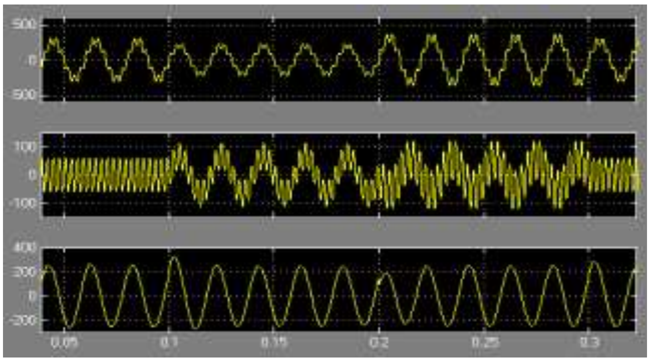


Fig 6.2 BUS1 voltage, series compensating voltage, and load voltage in Feeder1.

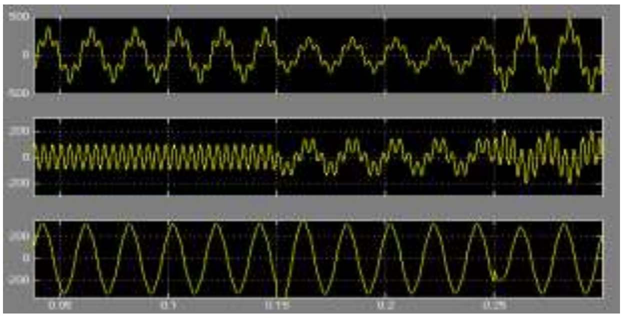


Fig 6.3 BUS2 voltage, series compensating voltage, and load voltage in Feeder2.

Additionally, the BUS2 voltage, the relating compensation voltage infused by VSC3, and at last, the load L2 voltage are shown in Fig. 6.3. As shown in these figures, mutilated voltages of BUS1 and BUS2 are palatably adjusted for over the loads L1 and L2 with great unique reaction.

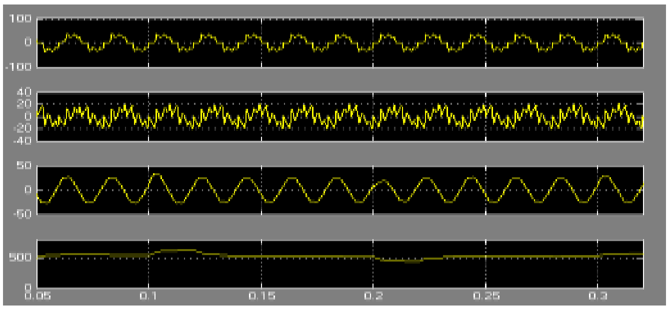


Fig 6.4 Nonlinear load current, compensating current, Feeder1 current, and Capacitor voltage.

The nonlinear load current, its comparing compensation current infused by VSC2, repaid Feeder1 current, and, at last, the dc-connect capacitor voltage are shown in Fig. 6.4. The twisted nonlinear load current is remunerated extremely well, and the aggregate harmonic distortion (THD) of the feeder current is lessened from 28.5% to under 5%. Likewise, the dc voltage direction loop has worked legitimately under all aggravations, such as droop/swell in both feeders.

6.2.2 Upstream Fault on Feeder2

When a fault happens in Feeder2 (in any type of L-G, L-L-G, and L-L-L-G faults), the voltage over the touchy/basic load L2 is engaged with list/swell or interruption. This voltage blemish can be made up for by VSC2.

For this situation, the power required by load L2 is supplied through VSC2 and VSC3. This infers that the power semiconductor switches of VSC2 and VSC3 must be evaluated such that aggregate power exchange is conceivable. This may expand the expense of the device, however the advantage that might be acquired can counterbalance the cost.

In the proposed configuration, the delicate/basic load on Feeder2 is completely secured against distortion, droop/swell, and interruption. Furthermore, the directed voltage over the delicate load on Feeder1 can supply a few clients who are additionally secured against distortion, hang/swell, and flitting interruption. Therefore, the expense of the MC-UPQC must be adjusted against the expense of interruption, based on unwavering quality records, such as the client normal interruption duration file (CAIDI) and client normal interruption frequency file (CAIFI). It is normal that the MC-UPQC cost can be recuperated in a couple of years by charging higher levies for the secured lines.

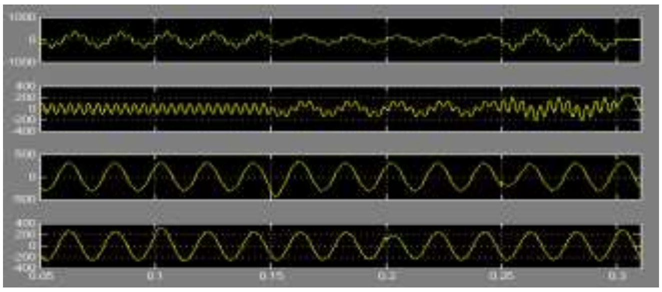


Fig 6.5 Simulation results for an upstream fault on Feeder2: BUS2 voltage, compensating voltage, and loads L_1 and L_2 voltages.

The execution of the MC-UPQC under a fault condition on Feeder2 is tried by applying a three-phase fault to ground on Feeder2 between s. Reproduction results are shown in Fig.6.5.

6.2.3 LOAD CHANGE

To assess the system behavior amid a load change, the nonlinear load L1 is multiplied by diminishing its protection from half at 0.5 s. The other load, however, is kept unchanged. The system reaction is shown in Fig. 6.6. It tends to be seen that as load L1 changes, the load voltages and stay undisturbed, the dc bus voltage is controlled, and the nonlinear load current is redressed.

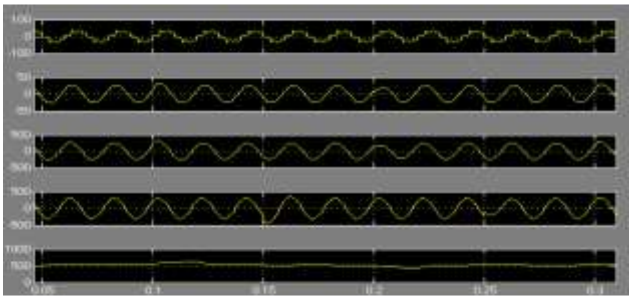


Fig 6.6. Simulation results for load change: nonlinear load current, Feeder1 current, load L_1 voltage, load L_2 voltage, and dc-link capacitor voltage.

6.2.4 UNBALANCE VOLTAGE

The control strategies for shunt and series VSCs, which are introduced in Section II, are based on the – method. They are capable of compensating for the unbalanced source voltage and unbalanced load current. To evaluate the control system capability for unbalanced voltage compensation, a new simulation is performed. In this new simulation, the BUS2 voltage and the harmonic components of BUS1 voltage are similar to those given in Section IV. However, the fundamental component of the BUS1 voltage is an unbalanced three-phase voltage with an unbalance factor of 40%. This unbalance voltage is given by

The simulation results for the three-phase BUS1 voltage, series compensation voltage, and load voltage in feeder 1 are shown in Fig. 6.8. The simulation results show that the harmonic components and unbalance of under unbalanced source voltage for by injecting the proper series voltage. In this figure, the load voltage is a three-phase sinusoidal balance voltage with regulated amplitude.

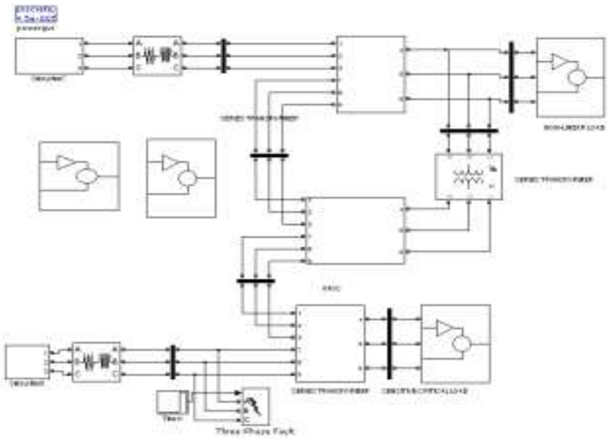


Fig 6.7 Simulation diagram of MC-UPQC for showing results in unbalanced condition.

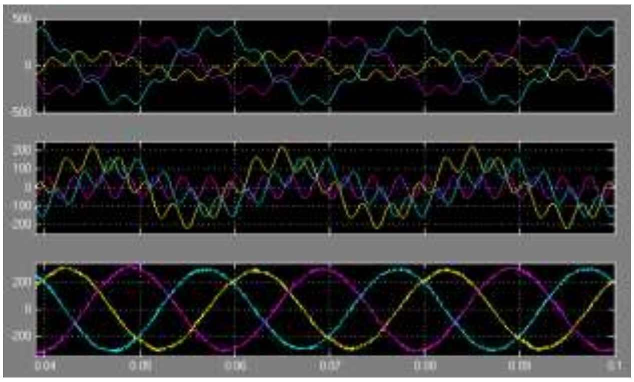


Fig 6.8 BUS1 voltage, series compensating voltage and load voltage in Feeder1 under unbalanced source voltage.

CONCLUSION

In this project, another configuration for concurrent compensation of voltage and current in neighboring feeders has been proposed. The new configuration is named multi-converter bound together power-quality conditioner (MC-UPQC). Contrasted with a conventional UPQC, the proposed topology is prepared to do completely securing basic and delicate loads against distortions, lists/swell, and interruption in two-feeder systems. The thought can be theoretically stretched out to multibus/multifeeder systems by including more series VSCs. The execution of the MC-UPQC is assessed under different unsettling influence conditions and it is shown that the proposed MC-UPQC offers the accompanying preferences:

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