IMPROVED CONTROLLER FOR THE DUAL TOPOLOGY OF THE UNIFIED POWER QUALITY CONDITIONER (IUPQC) IN POWER-QUALITY COMPENSATION AND MICROGRID APPLICATIONS

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Abstract:- *This project presents an improved controller for the dual topology of the unified power quality conditioner (iUPQC) extending its applicability in power-quality compensation, as well as in micro grid applications. By utilizing this controller, past the ordinary UPQC power quality elements, including voltage sag/swell pay, the iUPQC will likewise give receptive power support to manage the heap bus voltage as well as the voltage at the grid-side bus. At the end of the day, the iUPQC will act as a static synchronous compensator (STATCOM) at the grid side, while giving likewise the ordinary UPQC remunerations at the heap or micro grid side. Exploratory outcomes are given to confirm the new usefulness of the hardware.*

Index Terms—iUPQC, microgrids, power quality, static synchronous compensator (STATCOM), unified power quality conditioner (UPQC).

INTRODUCTION

Voltage sag is a standout amongst the most critical issues confronting mechanical and extensive business clients [15]. As of late, utilities have been confronted with an expanding number of grievances about voltage sag. The most well-known reason for voltage sag is power system shortcomings, despite the fact that lightning strikes and engine begins are likewise reasons for this issue. Single line-to-ground deficiencies are in charge of the larger part of occurrences of voltage sag on the system, and are equipped for delivering a decrease to 33% of the ostensible voltage. Three-stage deficiencies are less normal, nonetheless they are related with more extreme issues. Another factor which impacts the magnitude of the sag is the area of the blame. A client arranged in closeness to a blame will encounter a more serious voltage sag than a client situated at a more noteworthy separation from the blame. Hardware, for example, PCs, prepare controllers, and power electronic device are infamous for their affectability to power quality unsettling influences. DC drives and chiller controls are additionally very touchy, and can stumble on a lessening in the voltage as little as 10%. Voltage sag is to a great degree troublesome, if not difficult to forestall, in spite of the fact that it is conceivable to diminish the impact on equipment. The voltage sags as characterized by IEEE Standard 1159, IEEE Recommended Practice for Monitoring Electric Power Quality, is ―a diminish in RMS voltage or current at the power recurrence for terms from 0.5 cycles to 1 minute, detailed as the rest of the voltage‖. Ordinary esteems are between 0.1 p.u. what's more, 0.9 p.u., and run of the mill blame clearing times extend from three to thirty cycles contingent upon the blame current magnitude and the kind of finished current location and interference. Phrasing used to depict the magnitude of voltage sag is frequently confounding. The prescribed phrasing as indicated by IEEE Std. 1159 is ―the sag to 20%,‖ which implies that line voltage is decreased to 20% of typical esteem. Another definition as given in IEEE Std. 1159, 3.1.73 is ―A variety of the RMS estimation of the voltage from ostensible voltage for a period more noteworthy than 0.5 cycles of the power recurrence yet not exactly or equivalent to 1 minute.

Surely, power-hardware device have achieved extraordinary mechanical changes. Be that as it may, the expanding number of power-hardware driven burdens utilized for the most part in the business has realized exceptional power quality issues. Interestingly, power-device driven loads for the most part require perfect sinusoidal supply voltage with a specific end goal to work legitimately, while they are the most mindful ones for anomalous consonant streams level in the conveyance system. In this situation, device that can relieve these disadvantages have been created throughout the years. A portion of the arrangements include an adaptable compensator, known as the unified power quality conditioner (UPQC) [l]–[7] and the static synchronous compensator (STATCOM) [8]–[l3]. The power circuit of an UPQC comprises of a blend of a shunt dynamic channel and an arrangement dynamic channel associated in a consecutive setup. This blend permits the concurrent pay of the heap current and the supply voltage, so the remunerated current drawn from the lattice and the repaid supply voltage conveyed to the heap are kept adjusted and sinusoidal. The double topology of the UPQC, i.e., the iUPQC, was introduced in [l4]–[l9], where the shunt Active channel carries on as an air conditioner voltage source and the arrangement one as an air conditioner current source, both at the major recurrence. This is a key point to better plan the control picks up, and in addition to streamline the LCL channel of the power converters, which permits enhancing altogether the general execution of the compensator [20]. The STATCOM has been utilized broadly in transmission systems to manage the voltage by methods for dynamic responsive power pay. These days, the STATCOM is to a great extent utilized for voltage control [9], though the UPQC and the iUPQC have been chosen as answer for more particular applications[2l]. In addition, these last ones are utilized just specifically cases, where their moderately high expenses are supported by the power quality change it can give, which would be unfeasible by utilizing traditional arrangements. By joining the additional usefulness like a STATCOM in the iUPQC gadget, a more extensive situation of uses can be come to, especially on the off chance that o circulated era in savvy systems and as the coupling gadget in network tied micro grids. In [l6], the execution of the iUPQC and the UPQC was looked at when filling in as UPQCs. The fundamental contrast between these compensators is the kind of source imitated by the arrangement and shunt power converters. In the UPQC approach, the arrangement converter is controlled as a non-sinusoidal voltage source and the shunt one as a non-sinusoidal current source. Thus, progressively, the UPQC controller needs to decide and combine precisely the consonant voltage and current to be adjusted. Then again, in the iUPQC approach, the arrangement converter carries on as a controlled sinusoidal current source and the shunt converter as a controlled sinusoidal voltage source. This implies it is not important to decide the consonant voltage and current to be adjusted, since the symphonious voltages show up normally over the arrangement current source and the symphonious streams stream actually into the shunt voltage source. In real power converters, as the exchanging recurrence expands, the power rate capacity is lessened. In this manner, the iUPQC offers better arrangements if contrasted and the UPQC in the event of high-power applications, since the iUPQC remunerating references are unadulterated sinusoidal waveforms at the basic recurrence. In addition, the UPQC has higher changing misfortunes because of its higher exchanging recurrence.

This venture proposes an enhanced controller, which grows the iUPQC functionalities. This enhanced adaptation of iUPQC controller incorporates all functionalities of those past ones, including the voltage direction at the heap side transport, and now giving likewise voltage direction at the network side transport, similar to a STATCOM to the matrix. Reenactment comes about are given to approve the new controller outline.

MODIFIED IUPQC CONFIGURATION

Keeping in mind the end goal to clear up the relevance of the enhanced iUPQC controller, Fig. l delineates an electrical framework with two transports in spotlight, i.e., transport An and transport B. Transport A will be a basic transport of the power framework that provisions delicate loads and fills in as purpose of coupling of a microgrid. Transport B is a transport of the microgrid, where nonlinear burdens are associated, which requires premium-quality power supply. The voltages at transports An and B must be directed, with a specific end goal to legitimately supply the touchy burdens and the nonlinear burdens. The impacts caused by the consonant streams drawn by the nonlinear burdens ought to be relieved, staying away from symphonious voltage engendering to transport A. The utilization of a STATCOM to ensure the voltage direction at transport An is insufficient in light of the fact that the consonant streams drawn by the nonlinear burdens are not moderated. Then again, an UPQC or an iUPQC between transport An and transport B can repay the symphonious streams of the nonlinear loads and remunerate the voltage at transport B, regarding voltage sounds, unbalance, and sag/swell. In any case, this is as yet insufficient to ensure the voltage direction at transport A. Henceforth, to accomplish all the coveted objectives, a STATCOM at transport An and an UPQC (or an iUPQC) between transports An and B ought to be utilized. Be that as it may, the expenses of this arrangement would be nonsensically high. An appealing arrangement would be the utilization of a changed iUPQC controller to give likewise receptive power support to transport A, notwithstanding each one of those functionalities of this hardware, as displayed in [l6] and [l8]. Note that the altered iUPQC fills in as an intertie between transports An and B. Also, the microgrid associated with the transport B could be a mind boggling framework including disseminated era, vitality administration framework, and other control frameworks including microgrid, and also savvy grid ideas

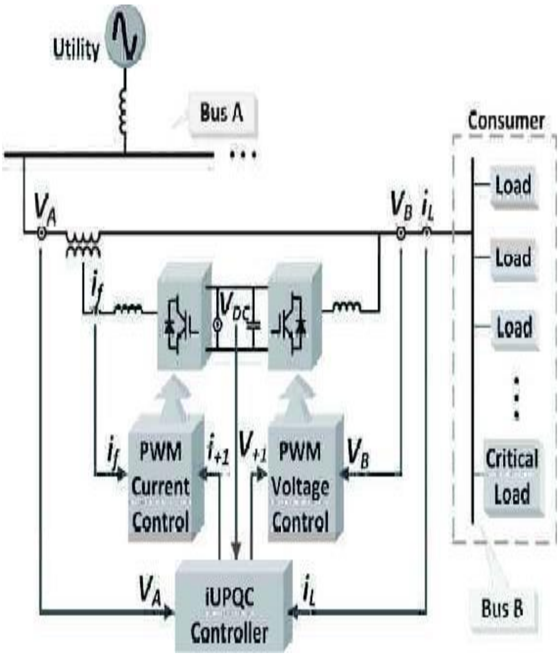

Fig. 1. Modified iUPQC configuration

Fig. 2 depicts, in detail, the connections and measurements of the iUPQC between bus A and bus B. According to the conventional iUPQC controller, the shunt converter imposes a controlled sinusoidal voltage at bus B, which corresponds to the aforementioned functionality (d). As a result, the shunt converter has no further degree of freedom in terms of compensating active- or reactive-power variables to expand its functionality. On the other hand, the series converter of a conventional iUPQC uses only an active- power control variable *p*, in order to synthesize a fundamental sinusoidal current drawn from bus A, corresponding to the active power demanded by bus B. If the dc link of the iUPQC has no large energy storage system or even no energy source, the control variable *p* also serves as an additional active-power reference to the series converter to keep the energy inside the dc link of the iUPQC balanced. In this case, the losses in the iUPQC and the active power supplied by the shunt converter must be quickly compensated in the form of an additional active power injected by the series converter into the bus B.

PROPOSED CONCEPT

IMPROVED IUPQC CONTROLLER

Main Controller:

Fig. 2 delineates the iUPQC equipment and the deliberate units of a three-stage three-wire framework that are utilized as a part of the controller. Fig. 3 demonstrates the proposed controller. The controller inputs are the voltages at transports An and B, the current requested by transport B (iL), and the voltage vDC of the basic dc connect. The yields are the shunt-voltage reference and the arrangement current reference to the beat width adjustment (PWM) controllers. The voltage and current PWM controllers can be as basic as those utilized in [l8], or be enhanced further to better manage voltage and current irregularity and sounds [23]–[28]. To begin with, the disentangled Clark change is connected to the deliberate factors. As case of this change, the grid voltage in the aþ-reference casing can be figured as

$$\begin{bmatrix} V_{A\_\alpha} \\ V_{A\_\beta} \end{bmatrix} = \begin{bmatrix} 1 & 1/2 \\ 0 & \sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_{A\_ab} \\ V_{A\_bc} \end{bmatrix}. \qquad (1)$$

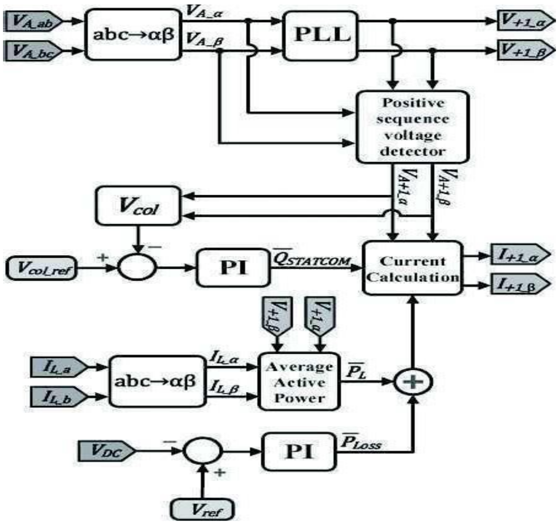

Fig. 2. Novel iUPQC controller.

The shunt converter forces the voltage at transport B. Subsequently, it is important to integrate sinusoidal voltages with ostensible plentifulness and recurrence. Subsequently, the signs sent to the PW controller are the stage bolted circle (PLL) yields with plentifulness equivalent to l p.u. There are numerous conceivable PLL calculations, which could be utilized as a part of this case, as checked in [29]–[33]. In the first iUPQC approach as introduced in [l4], the shunt-converter voltage reference can be either the PLL yields or the essential positive-grouping segment VA+l of the grid voltage (transport An in Fig. 2). The utilization of VA+l in the controller is helpful to limit the coursing power through the arrangement and shunt converters, under typical operation, while the plentifulness of the grid voltage is inside a worthy scope of magnitude. Be that as it may, this is not the situation here, in the altered iUPQC controller, since now the grid voltage will be additionally managed by the adjusted iUPQC. As such, the two transports will be controlled freely to track their reference esteems. The arrangement converter combines the current drawn from the grid (transport A). In the first approach of iUPQC, this current is figured through the normal dynamic power required by the heaps PL in addition to the power PLoss. The heap dynamic power can be assessed by

$$P_L = V_{+1\_\alpha} \cdot i_{L\_\alpha} + V_{+1\_\beta} \cdot i_{L\_\beta} \qquad (2)$$

where iL_a, iL_þ are the heap streams, and V+l_a, V+l_þ are the voltage references for the shunt converter. A low-pass channel is utilized to acquire the normal active power (PL). The misfortunes in the power converters and the circling power to give vitality adjust inside the iUPQC are figured in a roundabout way from the estimation of the dc-interface voltage. At the end of the day, the power flag PLoss is dictated by a proportional– necessary (PI) controller (PI hinder in Fig. 3), by contrasting the deliberate dc voltage VDC and its reference esteem. The extra control circle to give voltage direction like a STATCOM at the grid transport is spoken to by the control flag QSTATCOM in Fig. This control flag is acquired through a PI controller, in which the info variable is the blunder between the reference esteem and the real total voltage of the grid bus,given by

$$V_{\mathrm{col}} = \sqrt{V^2_{A+1\_\alpha} + V^2_{A+1\_\beta}}. \qquad (3)$$

The sum of the power signals *PL* and *P*Loss composes the active-power control variable for the series converter of the iUPQC (p). Likewise, *Q*STATCOM is the reactive- power control variable q. Thus, the current references *i*+l*a* and *i*+l*þ* of the series converter are determined by

$$\begin{bmatrix} i_{+1\_\alpha} \\ i_{+1\_\beta}\end{bmatrix} = \frac{1}{V^2_{A+1\_\alpha}+V^2_{A+1\_\beta}} \begin{bmatrix} V_{A+1\_\alpha} & V_{A+1\_\beta} \\ V_{A+1\_\beta} & -V_{A+1\_\alpha}\end{bmatrix} \times \begin{bmatrix}\overline{P}_L+\overline{P}_{\text{Loss}} \\ \overline{Q}_{\text{STATCOM}}\end{bmatrix}. \quad (4)$$

The following procedure, based on the average power flow, is useful for estimating the power ratings of the iUPQC converters.

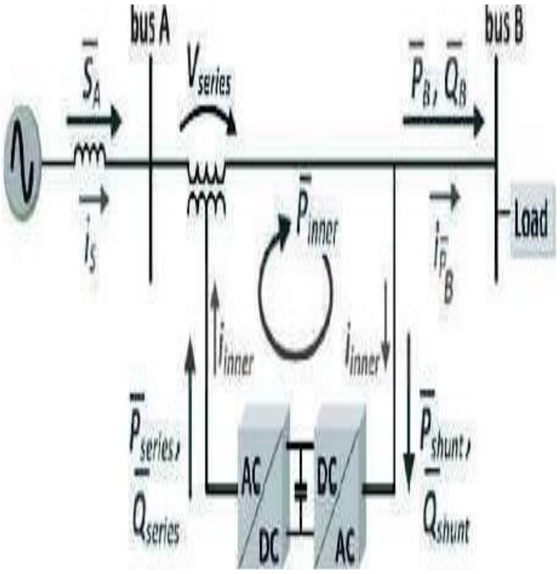

Fig. 4. iUPQC power flow in steady-state.

For consolidated series–shunt power conditioners, for example, the UPQC and the iUPQC, just the voltage sag/swell unsettling influence and the power factor (PF) remuneration of the heap deliver a coursing normal power through the power conditioners [34], [35]. As per Fig. 4, the remuneration of a voltage sag/swell unsettling influence at bus B causes a positive grouping voltage at the coupling transformer (Vseries _= 0), since VA _= VB. Also, Vseries and iPB in the coupling transformer prompts a flowing dynamic power Pinner in the iUPQC. Furthermore, the pay of the heap PF expands the current provided by the shunt converter. The accompanying investigation is substantial for an iUPQC acting like a regular UPQC or including the additional pay like a STATCOM. To begin with, the flowing power will be ascertained when the iUPQC is working quite recently like a customary UPQC. A while later, the conditions will incorporate the STATCOM usefulness to the grid bus A. In the two cases, it will be accepted that the iUPQ controller can compel the shunt converter of the iUPQC to create central voltage dependably in stage with the grid voltage at bus A. For effortlessness, the misfortunes in the iUPQC will be disregarded.

In a perfect world, the STATCOM usefulness mitigates the inward circle dynamic power stream (Pinner), and the power stream in the arrangement converter is zero. Subsequently, if the arrangement converter is appropriately outlined alongside the coupling transformer to orchestrate the controlled streams I+l_a and I+l_þ, as appeared in Fig. 3, at that point a lower power converter can be utilized. Oppositely, the shunt converter still needs to give the full responsive power of the heap and furthermore to deplete the receptive power infused by the arrangement converter to direct the voltage at bus A.

Parameter	Value
Voltage	220 V rms
Grid frequency	60 Hz
Power rate	5 kVA
DC-link voltage	450 V dc
DC-link capacitors	C = 9400 µF
Shunt converter passive filter	L = 750 µH R = 3.7 Ω C = 20.0 µF
Series converter passive filter	L = 1.0 mH R = 7.5 Ω C = 20.0 µF
Sampling frequency	19440 Hz
Switching frequency	9720 Hz
PI controller ($\overline{P}_{loss}$)	Kp = 4.0 Ki = 250.0
PI controller ($\overline{Q}_{STATCOM}$)	Kp = 0.5 Ki = 50.0

SYSTEM DESCRIPTION

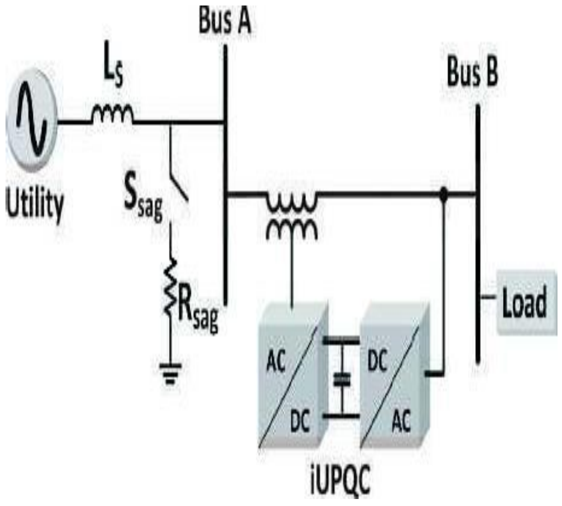

Fig..5. iUPQC experimental scheme

VSC based custom power device are progressively being utilized as a part of custom power applications for enhancing the power quality (PQ) of power circulation frameworks. Device, for example, dispersion static compensator (DSTATCOM) and dynamic voltage restorer (DVR) have just been talked about widely in [l]. A DSTATCOM can make up for bending and unbalance in a heap to such an extent that an adjusted sinusoidal current moves through the feeder [2]. It can likewise control the voltage of an appropriation bus [3], [4]. A DVR can adjust for voltage sag/swell and mutilation in the supply side voltage with the end goal that the voltage over a touchy/basic load terminal is flawlessly directed [5], [6]. A unified power-quality conditioner (UPQC) can play out the elements of both DSTATCOM and DVR [7], [8]. The UPQC comprises of two voltage-source converters (VSCs) that are associated with a typical dc bus. One of the VSCs is associated in arrangement with a circulation feeder, while the other one is associated in shunt with a similar feeder. The dc connections of both VSCs are provided through a typical dc capacitor. It is likewise conceivable to interface two VSCs to two unique feeders in a dissemination framework. In [9], a setup called IDVR has been talked about in which two DVRs are associated in arrangement with two separate contiguous feeders. The dc busses of the DVRs are associated together. The IDVR retains genuine power from one feeder and keeps up the dc interface voltage to moderate 40% (around 0.6 p.u.) voltage sag in the other feeder with adjusted burdens associated in the circulation framework. It is likewise conceivable to associate two shunt VSCs to various feeders through a typical dc connect. This can likewise play out the elements of the two DVRs said above, yet with higher gadget rating. This paper shows another association for an UPQC called interline UPQC (IUPQC). The single-line graph of an IUPQC associated dispersion framework is appeared in Fig. l. Two feeders, Feeder-l and Feeder-2, which are associated with two unique substations, supply the framework loads L-1 and L-2. The supply voltages are indicated by and It is expected that the IUPQC is associated with two busses B-l and B-2, the voltages of which are signified by and , separately. Assist two feeder streams are indicated by and keeping in mind that the heap ebbs and flows are meant by and .The motivation behind the IUPQC is to hold the voltages Vtl and Vt2 steady against voltage sag/swell, brief intrusion in both of the two feeders. It has been shown that the IUPQC can retain power from one feeder (say Feeder-l) to hold Vt2 consistent if there should arise an occurrence of a sag in the voltage Vs2 . This can be refined as the two VSCs are provided by a typical dc capacitor. The dc capacitor voltage control has been talked about here alongside voltage reference era methodology. Additionally, the breaking points of achievable execution have been figured. The execution of the IUPQC has been assessed through simulation studies using SIMULINK

SIMULATION RESULTS:

The enhanced iUPQC controller, as appeared in Fig. 3, was confirmed in a 5-kVA model, whose parameters are exhibited in Table I. The controller was implanted in a settled point computerized flag processor (TMS320F2812). Keeping in mind the end goal to confirm all the power quality issues portrayed in this paper, the iUPQC was associated with a grid with a voltage sag framework, as delineated in Fig. 6. The voltage sag framework was formed by an inductor (LS), a resistor (RrmSag), and abreaker (SSag). To cause a voltage sag at bus A, SSag is shut. At to start with, the source voltage direction was tried with no heap associated with bus B. For this situation, the iUPQC carries on as a STATCOM, and the breaker SSag is shut to cause the voltage sag. To check the grid-voltage direction (see Fig. 7), the control of the QSTATCOM variable is empowered to form (4) at moment t = 0 s. In this exploratory case, LS = 10 mH, and RSag = 7.5 う. Before the QSTATCOM variable is empowered, just the dc interface and the voltage at bus B are controlled, and there is a voltage sag at bus An, as appeared in Fig. After t = 0s, the iUPQC begins to draw receptive current from bus An, expanding the voltage until the point when its reference esteem.

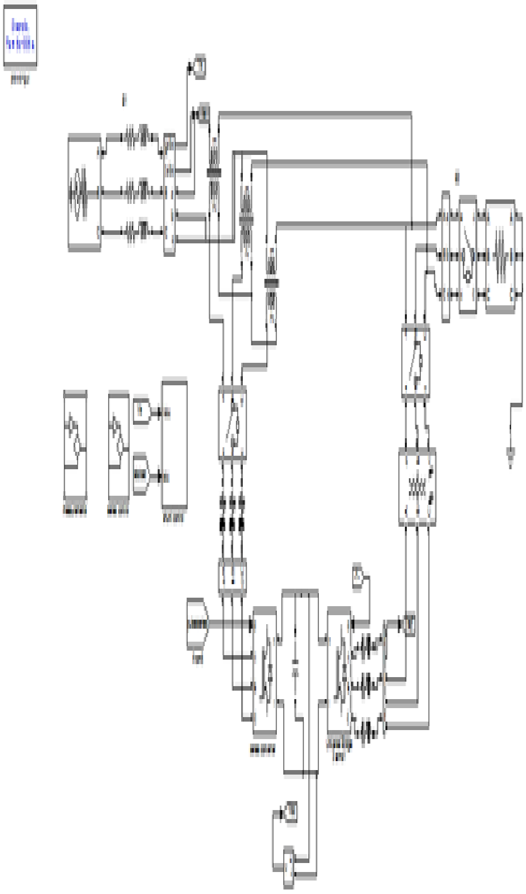

Fig 6 Simulink Diagram

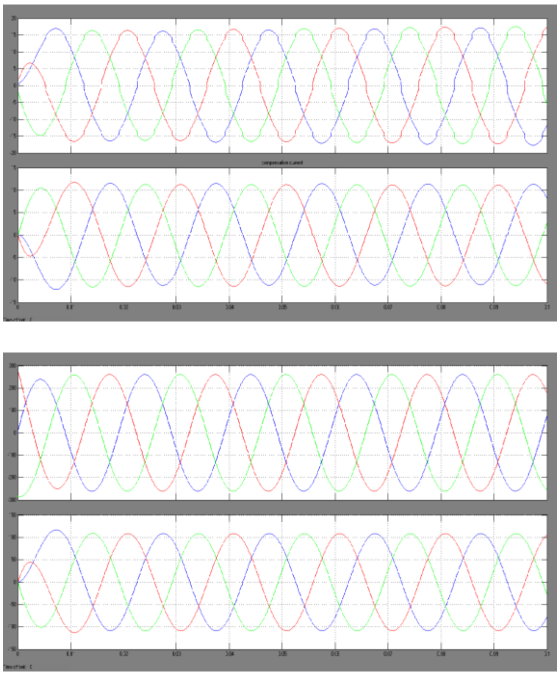

Fig 7 iUPQC response at no load condition: (a) grid voltages *VA*, (b) load voltages *VB*,

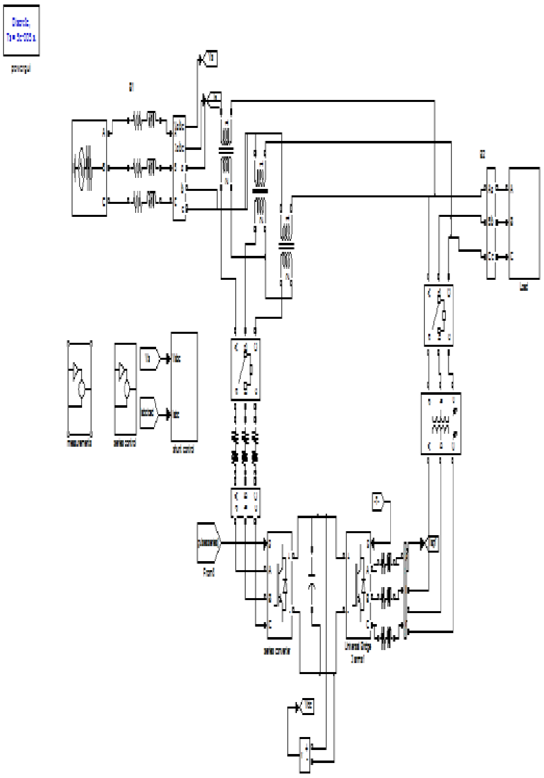

Fig 8 simulink diagram

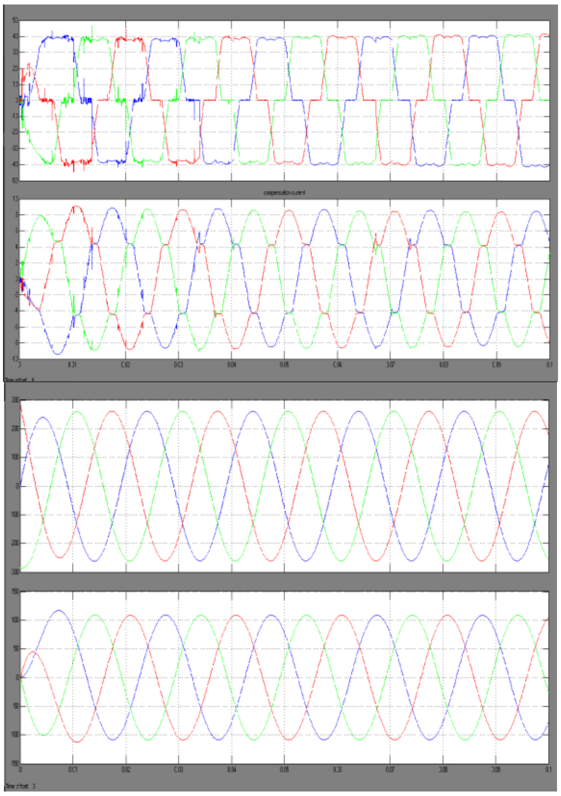

Fig 9 iUPQC transitory response during the connection of a threephase diode rectifier: (a) load currents, (b) grid currents, (c) load voltages and (d) grid voltages.

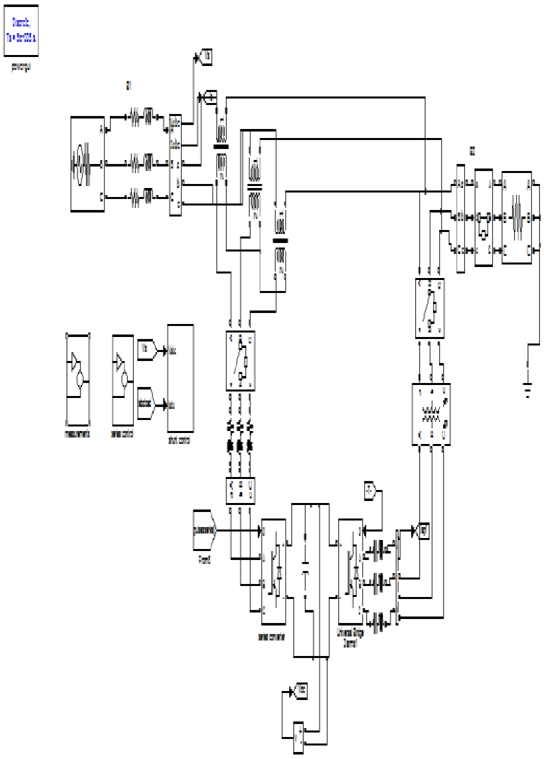

Fig 10 Simulink Diagram

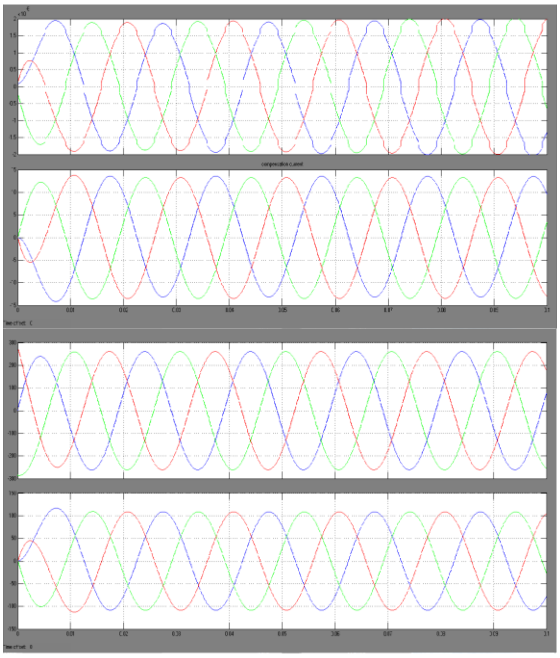

Fig 11 iUPQC transitory response during the connection of a two phase diode rectifier: (a) load currents, (b) source currents, (c) load voltages, and (c) source voltages.

CONCLUSION

In the enhanced iUPQC controller, the streams orchestrated by the arrangement converter are dictated by the normal dynamic power of the heap and the dynamic power to give the dc-connect voltage direction, together with a normal responsive power to manage the grid-bus voltage. In this way, notwithstanding all the power-quality pay elements of a customary UPQC or an iUPQC, this enhanced controller additionally imitates a STATCOM to the grid bus. This new element upgrades the appropriateness of the iUPQC and gives new arrangements in future situations including shrewd grids and microgrids, including circulated era and vitality stockpiling frameworks to better manage the inalienable inconstancy of inexhaustible assets, for example, sun powered and wind power. Additionally, the enhanced iUPQC controller may legitimize the expenses and advances the iUPQC materialness in power quality issues of basic frameworks, where it is fundamental an iUPQC or a STATCOM, as well as both, all the while. Regardless of the expansion of one more power-quality remuneration include, the grid-voltage control diminishes the inward circle coursing power inside the iUPQC, which would permit bring down power rating for the arrangement converter. The test comes about checked the enhanced iUPQC objectives. The grid-voltage direction was accomplished with no heap, and in addition when providing a three-stage nonlinear load. These outcomes have exhibited an appropriate execution of voltage direction at the two sides of the iUPQC, even while remunerating consonant current and voltage irregular characteristics.

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