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Power Quality Improvement Using UPQC with variable DC Link Voltage Control

Ashish Awasthi[1], Prof. Vivek Rai[2]

[1]Research Scholar, Department of Electrical and Electronics, LNCT BHOPAL (M.P.)
[2]Assistant Professor, Department of Electrical and Electronics, LNCT BHOPAL (M.P.)

ABSTRACT
This method is used to optimize dc-link voltage of Unified Power Quality Conditioner (UPQC) based on load compensation requirement using Reduced Switch Count Multi-Level Converter (RSC-MLC) integrated with Photo-Voltaic (PV) system. During off-peak loads, the dc-link voltage can be brought down to a lower value, which will reduce the voltage-stress across switches of inverter and minimizes the switching losses. The variation of dc-link voltage is provided using RSC-MLC which requires dc voltage supply. This method utilizes renewable resources of energy such as solar cells as the dc voltage source. This method is capable of compensating sags, swells, unbalance and harmonics demanded by three phase unbalanced and non-linear loads connected to the distribution side, leading to improvement of power quality. It is also capable of providing real power support to the load and thus prevents source from getting over loaded whenever required.

Keywords:- D-STATCOM .UPQC Power Quality, MATLAB.

INRODUCTION

The expansion of non-direct, inductive and unequal loads in the distribution system has prompted a few power quality issues [1]. It is because of quick ascent in the utilization of touchy hardware in modern, business, local and footing applications, for example, exchanged mode power supplies, PCs, coolers, TVs and so forth. The use side requests-controlled supply of power which includes the utilization of power electronic converters. The generators produce a sinusoidal voltage however the currents drawn by such loads are twisted and uneven. This influences the feeder voltage and prompts breaking down of different loads associated with a similar feeder. A few custom power gadgets (CPDs) have been utilized to beaten these issues [2], [3]. Out of these CPDs, Distribution Static Compensators (DSTATCOMs) are widely utilized for moderating the current-based power quality issues which incorporate poor power factor, uneven currents and expanded nonpartisan current.

A few D-STATCOM topologies and their plan have been canvassed in existing writing dependent on the prerequisite. Some regular techniques are 4-leg D-STATCOM and split-capacitor D-STATCOM [4], [5]. The 4-leg D-STATCOM topology utilizes one additional leg to give the way to unbiased current. This includes the utilization of additional changes prompting all the more exchanging misfortunes. Split capacitor D-STATCOM experiences capacitive voltage unbalance issue because of unequal charging of two capacitors at dc-interface. In this paper, 3-leg Voltage Source Inverter (VSI) topology with impartial capacitor has been utilized, which defeats these issues [6]. It utilizes just a single capacitor at the dc-interface, so there is no capacitor voltage unbalance. Additionally, there is no compelling reason to present an additional leg with two additional switches on the grounds that the impartial current remuneration is taken consideration by the small evaluated unbiased capacitor. Be that as it may, in the greater part of the referenced topologies, the dc-connect voltage is kept consistent dependent on appraised load conditions [7]. This prompts pointless exchanging misfortunes at decreased loads. The dc-interface voltage can be diminished at decreased loads for minimization of exchanging misfortunes related with Voltage Source Inverter (VSI) without influencing pay. In [8], versatile dc-interface voltage variety has been proposed utilizing PI controller. Be that as it may, it experiences moderate transient reaction because of the conduct of PI controller and prompts undulated dc-interface voltage which makes it questionable for quick evolving loads.

II THE BENEFITS OF POWER QUALITY

Power quality in the compartment terminal condition impacts the financial matters of the terminal task, influences dependability of the terminal hardware, and influences different purchasers served by a similar utility administration. Every one of these worries is investigated in the accompanying sections.

2.2 POWER FACTOR PENALTIES

Numerous service organizations conjure punishments for low power factor on month to month billings. There is no industry standard pursued by service organizations. Techniques for metering and figuring power factor punishments fluctuate starting with one service organization then onto the next. Some service organizations really meter kVAR use and build up a fixed rate times the quantity of kVAR-hours devoured. Other service organizations screen kVAR requests and compute power factor. In the event that the power factor falls beneath a fixed utmost incentive over an interest period, a punishment is charged as a change in accordance with the pinnacle request charges. Various service organizations adjusting compartment terminal gear don't yet summon power factor punishments. In any case, their administration contract with the Port may even now necessitate that a base power factor over a characterized interest period be met. The service organization may not constantly screen power factor or kVAR utilization and reflect them in the month to month utility billings; be that as it may, they do claim all authority to screen the Port administration whenever. On the off chance that the power factor criteria put forward in the administration contract are not met, the client might be punished, or required to take restorative activities at the client's cost. One service organization, which supplies power administration to a few east coast compartment terminals in the USA, does not reflect power consider punishments their month to month billings, be that as it may, their administration contract with the terminal peruses as pursues:

The normal power factor under working states of client's load at the point where administration is metered will be at the very least 85%. On the off chance that underneath 85%, the client might be required to outfit, introduce and keep up to its detriment restorative mechanical assembly which will expand the Power factor of the whole establishment to at the very least 85%. The client will guarantee that no intemperate harmonics or homeless people are acquainted on with the [utility] system. This may require uncommon power molding hardware or filters. The IEEE Std. 519-1992 is utilized as a guide in determining proper plan prerequisites.

The Port or terminal tasks work force, who are in charge of keeping up holder cranes, or indicating new compartment crane hardware, ought to know about these prerequisites. Utility deregulation will probably constrain utilities to implement prerequisites, for example, the model above.

Terminal administrators who don't manage punishment issues today might be looked with some fairly extreme punishments later on. A sound, future terminal development plan ought to incorporate possibilities for tending to the conceivable financial effect of utility deregulation.

III CONTROL STRATEGIES

The generators produce a sinusoidal voltage but the currents drawn by such loads are distorted and unbalanced. This affects the feeder voltage and leads to malfunctioning of other loads connected to the same feeder. Several custom power devices (CPDs) have been used to overcome these issues [2], [3]. Out of these PDs, Distribution Static Compensators (DSTATCOMs) are extensively used for mitigating the current-based power quality problems which include poor power factor, unbalanced currents and increased neutral current. Several DSTATCOM topologies and their design have been covered in existing literature based on the requirement. Some conventional methods are 4-leg DSTATCOM and split-capacitor DSTATCOM [4], [5]. The 4- leg DSTATCOM topology uses one extra leg to provide the path for neutral current. This involves the use of extra switches leading to more switching losses. Split capacitor DSTATCOM suffers from capacitive voltage unbalance problem due to unequal charging of two capacitors at dc-link.

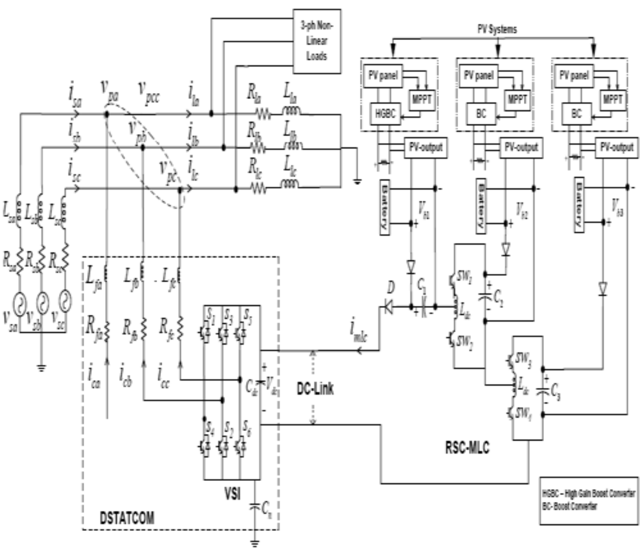

Fig 3.1: RSC-MLC controlled DSTATCOM for PQ improvement and real power injection from PV in distribution system.

However, in most of the mentioned topologies, the dc-link voltage is kept constant based on rated load conditions [7]. This leads to unnecessary switching losses at reduced loads. The dc-link voltage can be reduced at reduced loads for minimization of switching losses associated with Voltage Source Inverter (VSI) without affecting compensation. In [8], adaptive dc-link voltage variation has been proposed using PI controller. However, it suffers from slow transient response due to the behavior of PI controller and leads to rippled dc-link voltage which makes it unreliable for fast changing loads.

In the proposed method, the dc-link voltage regulation is achieved using Reduced Switch Count Multi Level Converter (RSC-MLC). The gate pulses of inverter switches are controlled using Hysteresis Controller which is faster and simpler [9]. The gate pulses are derived using Instantaneous Symmetrical Component Theory (ISCT) to get the reference harmonic currents based on load demand [10]. These harmonic currents are used to find the required reference dc-link voltage. The RSC-MLC is operated using Pulse Width Modulation (PWM) technique to obtain the desired level of dc-link voltage. The specialty of this RSC-MLC topology is reduced voltage stress at any operating condition across switches, which leads to reduction in switching losses.

In Fig. 3.2, I_{cmax} is maximum repaying current remunerated by D-STATCOM for a given evaluated load condition. The reference rms remunerating currents are gotten from the momentary reference repaying currents acquired utilizing ISCT, as given in equation (1).

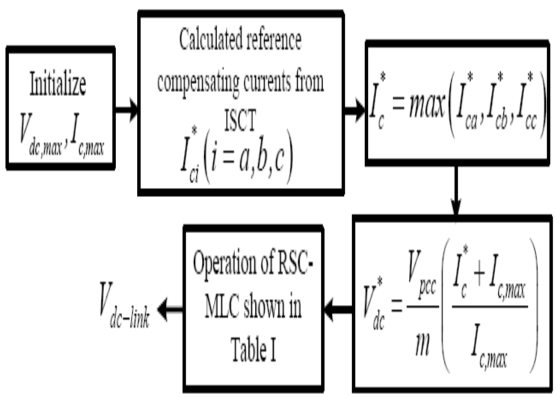

Fig 3.2: Flow-chart for reference dc-link voltage calculation.

$$i_{ck}^{*} = i_{lk} - \left(\frac{v_{sk}}{\sum_{j=a,b,c} v_{sj}^{2}}\right) P_i \quad (1)$$

Where, k = a, b and c stages. V_s is supply stage voltages, kind is load currents, yuck speaks to the reference repaying currents and Pl is the normal genuine power requested by the load. In any case, the final dc-connect voltage (V_{dc}) is chosen in view of the scopes of reference dc voltage (V_{dc}) utilizing RSC-MLC. The maximum dc-connect voltage ($V_{dc\ max}$) in the proposed technique is considered as twice of 1.6 occasions pinnacle of PCC voltage. The dc-connect voltage and comparing switches worked in RSC-MLC. The dc-interface voltage levels is separated similarly in ventures from $V_{dc,\ min}$ to $V_{dc,\ max.}$

The voltage extend from $V_{dc,min}$to $V_{dc,max}$ is partitioned to such an extent that with each resulting task of switch, the accompanying augmentation in voltage step (Vdc) Hence the voltage fluctuates in steps, for example, $V_{dc,min}$, ($V_{dc,min}$ + V_{dc}), ($V_{dc,min}$+ 2 V_{dc}), ..., $V_{dc,max}$, in view of the determined V_{dc} esteem comparing to load. The RSC-MLC is essentially a sort of buck-converter which ventures down the information dc voltage by the factor of obligation cycle. To get the ideal voltages, the switches of RSC-MLC are worked with certain obligation cycles. Here, the obligation cycle $d_1 = 1/3$ and $d_2 = 2/3$ are chosen to get the equivalent voltage division between $V_{dc,\ min}$ to $V_{dc,}$ max by getting the ideal addition V_{dc} in the dc- connect voltage. Here, $V_{dc,\ min}$ is same as the voltage crosswise over battery (V_{b1}) and $V_{dc,\ max} = V_{b1}+V_{b2}+V_{b3}$. By choice of such obligation cycles, the estimation of dc-connect voltage.

For instance:

(a) $V_{dc,\ min} = V_{b1}$ gotten by exchanging ON sw_2 and sw_4 for all time,

(b) $V_{dc,\ min}$ + $V_{b1}+V_{b2}+V_{b3}$ d1 and V_{dc}, min + 2 V_{dc} = V_{b1} + V_{b2} d2 are acquired by keeping sw_4 ON and working sw_1 with obligation cycles d1 and d2, separately. In the comparative manner, to get $V_{dc,max}$, sw_1 and sw_3 are exchanged ON for all time. The obligation cycles d1 and d2 are gotten and door pulses are created for the changes sw1 to sw4 utilizing sawtooth-step PWM method as appeared in Fig. 3.3. The entryway pulses are produced by contrasting transporter signal (c(t)) and adjusting signal (m(t)). In the event that c(t) > m(t), door pulse is rationale one (i.e., ON period (ton), generally rationale zero (i.e., OFF period). By shifting the greatness of tweaking signal, the ton time frame can be fluctuated, which is clarified underneath. From similitude of the triangles of the figure appeared in Fig. 3.3, the accompanying connection can be composed,

$$\frac{h}{T - t_{on}} = \frac{2}{T} \quad (2)$$

Where, T is absolute timespan of pulse, h be the greatness of adjusting signal. The statement of obligation cycle d for activity of switches can be given as $d = t_{on}/T$.

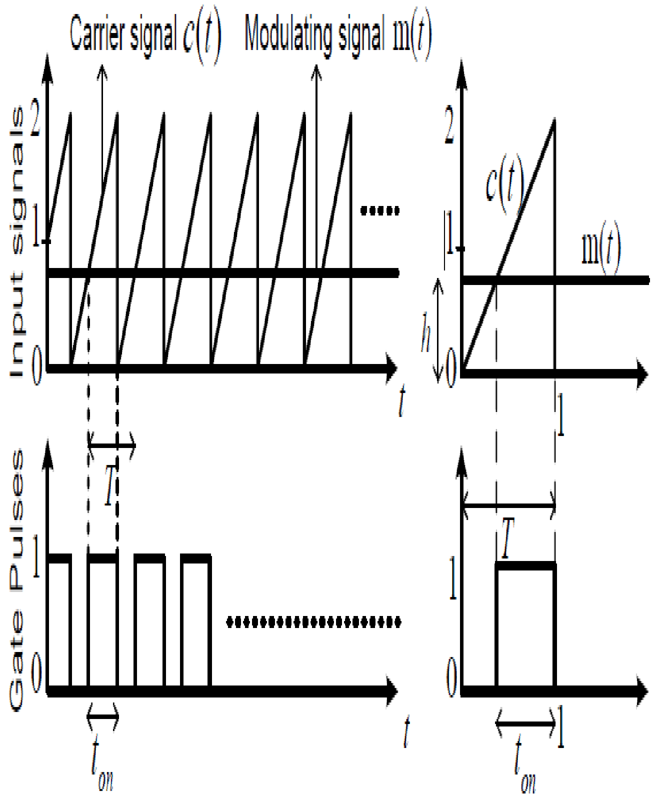

Fig 3.3: Generation of gate pulses from carrier signal and modulating signal.

By changing the recurrence of transporter signal, both the t_{on} and T changes, with the end goal that the obligation cycle stays same. Along these lines, for effortlessness in figuring, the timeframe T is downsized to 1 (for example T = 1). For obligation cycle d1 = 1/3, ton = 1/3, the determined an incentive from (3) is h = 4/3. Essentially, for obligation cycle d2 = 2/3, ton = 2/3, h = 2/3 is acquired.

Subsequently the balancing signals of size h = 4/3 and h = 2/3 is utilized to get d1 = 1/3 and d2 = 2/3 separately. By working the switches of RSC-MLC with these obligation cycles, the yield voltage levels can be changed in equivalent strides with improved flexibility Thus, at diminished loads, the exchanging misfortunes in VSI are limited as a result of decreased dc-connect voltage. Here, seven dc voltage levels have been accomplished utilizing the RSC-MLC appeared in Fig. 3.1. The modern power distribution system is winding up profoundly helpless against the different power quality issues. The broad utilization of non-direct loads is further adding to expanded current and voltage harmonics issues. Besides, the entrance dimension of small/enormous scale sustainable power source systems dependent on wind energy, sun-based energy, fuel cell, and so forth., introduced at distribution just as transmission levels is expanding significantly. Unified power quality control was generally examined by numerous specialists as an inevitable strategy to improve power nature of electrical distribution system. The capacity of unified power quality conditioner is to repay supply voltage flicker/unevenness, reactive power, negative sequence current, and harmonics.

As such, the UPQC has the ability of improving power quality at the point of establishment on power distribution systems or modern power systems. Hence, the UPQC is required to be a standout amongst the most powerful answers for huge limit loads delicate to supply voltage flicker/unevenness. The UPQC comprising of the blend of an arrangement active power filter (APF) and shunt APF can likewise remunerate the voltage interference on the off chance that it has some energy stockpiling or battery in the dc interface. The shunt APF is generally associated over the loads to make up for all current-related issues, for example, the reactive power pay, power factor improvement, current harmonics, remuneration, and load unbalance pay whereas the arrangement APF is associated in an arrangement with the line through arrangement transformers. It goes about as controlled voltage source and can remunerate all voltage related issues, for example, voltage harmonics, voltage hang, voltage swell, flicker, and so on.

The proposed control procedure has been assessed and tried under non-perfect mains voltage and unequal load conditions utilizing MATLAB/Simulink software. The proposed technique is likewise approved through trial examine. The accompanying graph demonstrates the summed up UPQC system the UPQC comprises of two voltage source inverters Connected consecutive with every one of them sharing a typical dc interface. Fig-4.2 demonstrates the control graph of UPQC system. One inverter fill in as a variable voltage source is called arrangement APF, and the different as a variable current source in called shunt APF. The fundamental point of the arrangement APF is consonant detachment among load and Supply; it has the capacity of voltage flicker/lop-sidedness remuneration just as voltage guideline and symphonies pay at the utility-shopper PCC. The shunt APF is utilized to assimilate current harmonics, make up for reactive power and negative-grouping current, and manage the dc connect voltage between both APFs.

IV RESULTS AND ANALYSIS

4.1 INTRODUCTION

In this chapter, various waveforms of D-STATCOM and UPQC are simulated in MATLAB Simulink and various input and output waveforms for the different conditions are shown below.

4.2 MATLAB D-STATCOM MODEL

MATLAB Simulink model for D-STATCOM model.

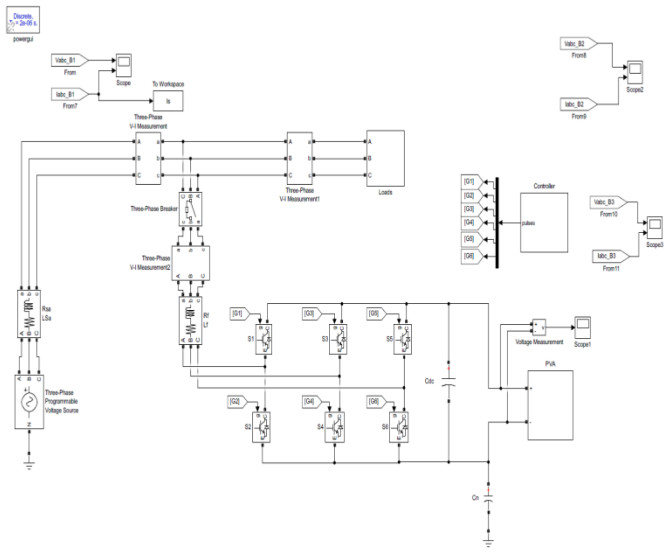

Fig 4.1: MATLAB Simulink model for D-STATCOM model.

The Input source Voltage (V_S) and Source Current (I_S) for the D-STATCOM model are shown below

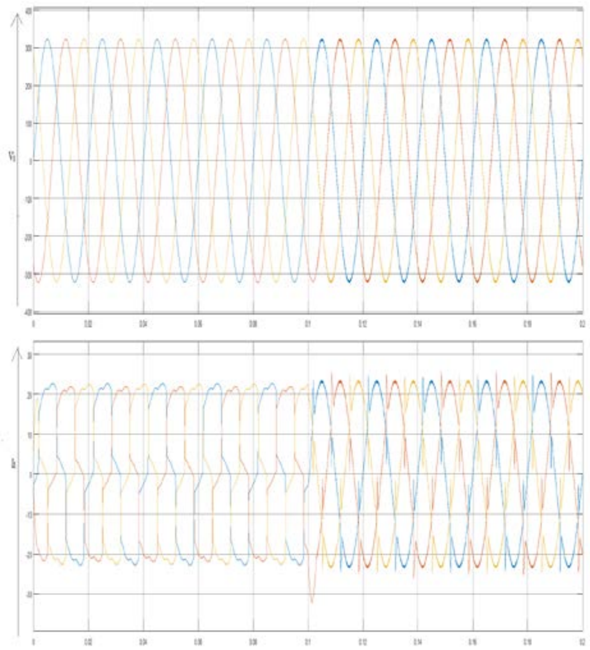

Fig 4.2: Input Waveforms, V_S and I_S for D-STATCOM model.

The Compensating Voltage (V_C) and Compensating Current (I_C) for the D-STATCOM model are shown below.

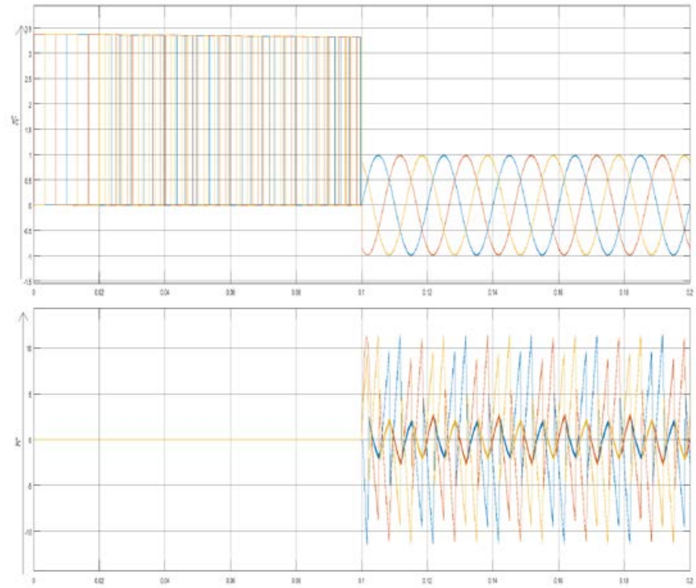

Fig 4.3: Compensating Voltage (V_C) and Compensating Current (I_C) for the D-STATCOM.

The Output waveforms for Load Voltage (V_L) and Load Current (I_L) are shown below and harmonics distortion are supressed compared to Input (V_S and I_S).

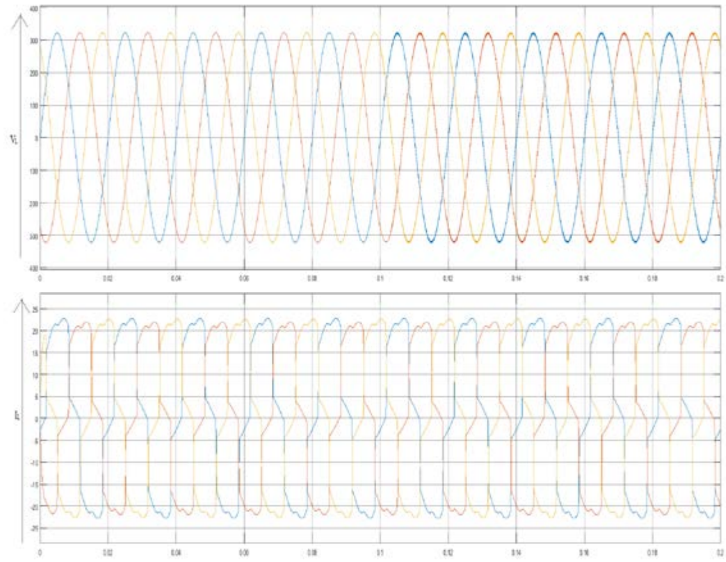

Fig 4.4: The Output waveforms for Load Voltage (V_L) and Load Current (I_L)

4.3 MATLAB MODEL FOR UPQC MODEL

MATLAB Simulink model for UPQC model.

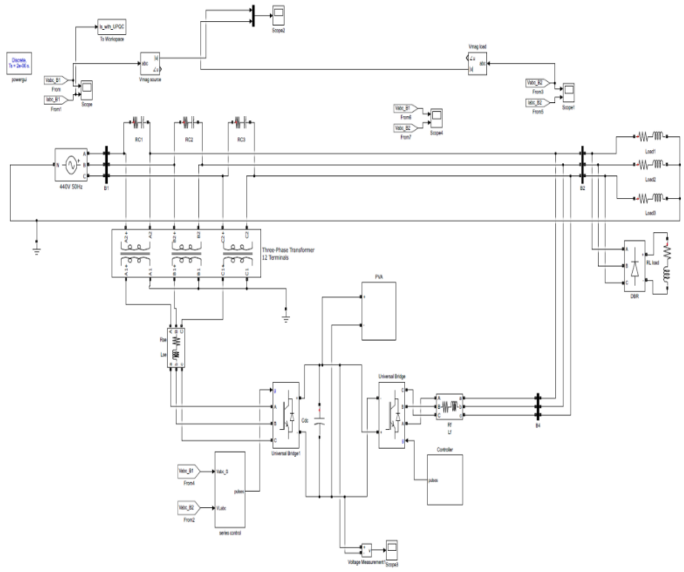

Fig 4.5: MATLAB Simulink model for UPQC model.

Voltage Sags and Swells Injected into the system from source side are shown below for UPQC model.

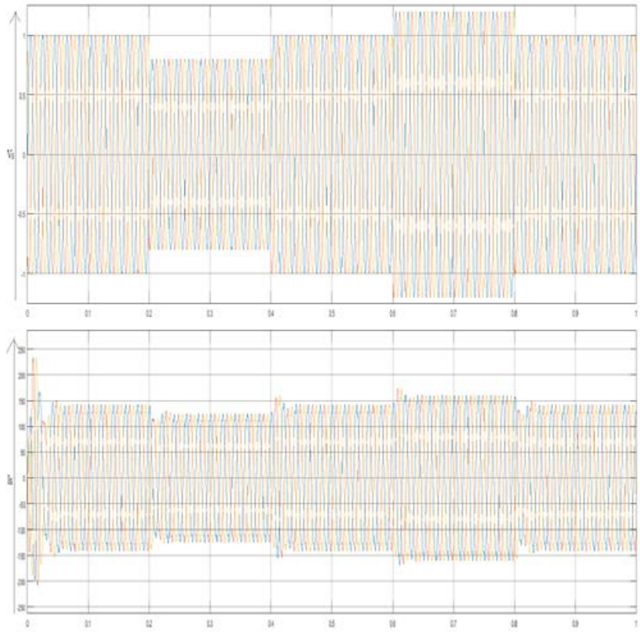

Fig 4.6: Voltage Sags and Swells Injection Voltage Sags and Swells Compensation are shown below for UPQC model.

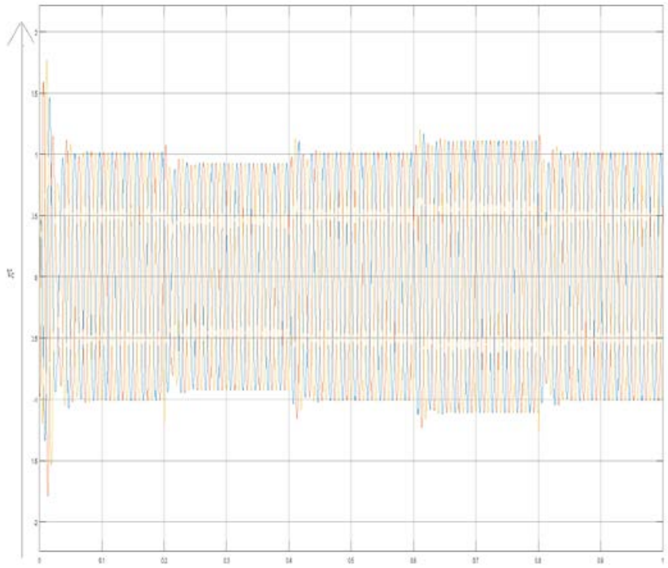

Fig 4.7: Voltage Sags and Swells Compensation Output Waveforms (V_L, I_L) are shown below for UPQC model.

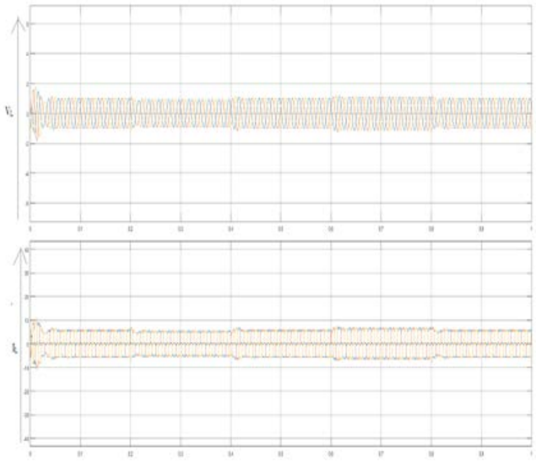

Fig 4.8: Output Waveforms (V_L, I_L).

V CONCLUSION AND FUTURE SCOPE

This technique is proposed to direct the dc-interface voltage utilizing the RSC-MLC influencing the presentation of UPQC. It likewise utilizes sustainable power source assets for acquiring dc voltage source, for example, PV boards, Fuel cells. Utilizing PV boards adequately empowers it to convey genuine power just as remuneration to the load amid day time and work simply as UPQC for power quality improvement during the evening. It very well may be seen from recreation and trial results that remuneration for reactive power and harmonics has been accomplished successfully. The source current is adjusted, sinusoidal, twisting free and with improved power factor. The %THD has decreased significantly after pay. Additionally, because of decreased dc-connect voltage at lesser loads, voltage worry over the switches has diminished and exchanging misfortunes are limited, as it were, expanding the life-time and efficiency of UPQC. Thus, it tends to be a decent option for power quality improvement and genuine power backing to the load.

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