Power Flow Control of Interconnected AC-DC Microgrids in Grid-Connected Hybrid Microgrids Using Modified UIPC

Ms.R.vanitha[a],Dr.P.Rangarajan[b] ,Ms.M.Uma Maheswari[c],Ms. P. M. Kalpana[d],Mr.U.Nagabalan[e]
[a]Assistant Professor, Department of EEE,R.M.D. Engineering College,vanitha7589@gmail.com
[b]Professor, Department of EEE,R.M.D. Engineering College,prr.eee@rmd.ac.in
[c]Assistant Professor, Department of EEE,R.M.D. Engineering College,uma.eee@rmd.ac.in
[d]Assistant Professor, Department of EEE,R.M.D. Engineering College,kalpana.eee@rmd.ac.in
[e]Assistant Professor, Department of EEE,R.M.D. Engineering College,unn.eee@rmd.ac.in

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ABSTRACT
A typical grid-connected hybrid microgrid has one AC microgrid and one DC microgrid, which is considered for this system. Alternate of deploying the parallel-connected power converters, these microgrids are having all constituent parts linked deploying to make partial changes UIPC. The traditional construction of UIPC, which conveys three power converters in each stage, is rolled out incomplete improvements so the check of power converters is executed for power trade control between AC-DC microgrids. The substitute situating involves one power converter in each stage, named as line power converter, and transport power converter. The AC microgrid is united to the main grid into the LPCs which their DC transports are related and can set off in capacitance mode. A fuzzy regulator is conveyed in the lead representative development of the LPCs. The fuzzy framework is registered dependent on H∞ separating strategy to diminish the mistakes in enrollment capacities design. From start to the completion the BPC, the DC voltage of LPCs is contributed by the DC microgrid. Nonetheless, since the DC microgrid voltage is on condition that here by a PV framework, the DC interface voltage of the LPCs is rising and falling sporadically in number. Subsequently, as the beneficiation to hold consistent the DC connect dissimilarities, another nonlinear unsettling influence eyewitness based powerful different surface sliding mode control game plan is administered for DC side control of the BPC. The results build up the adequacy of the set forward power stream control approach of the improved UIPC for mixture microgrids.

Key words: UIPC- Unified Interphase Power Flow Controller, line power converter (LPC)

1. INTRODUCTION

Recently, the DC power resources uses the renewable energy systems that mainly utilizes photovoltaic systems, fuel cells, wind, energy storage systems (ESSs) etc., In contrast, the AC power resources a kind that wind turbines and etc. notwithstanding the AC loads of a sort that electrical engines, and so on might be connected to the power frameworks into out of the AC microgrids. Later on keen matrices, the AC and DC microgrids involving AC and DC power assets and loads are integrate as a power converter framework. In a real sense, the AC and DC microgrids are connected in to and out of the power converters. This association permits the microgrids to trade power when it required. The power converters are generally associated in corresponding to trade measure of power and increment unwavering quality .The DC microgrid could involves PV frameworks, ESSs and related loads, which are connected to a common DC transport. The AC microgrid may contain wind turbine, diesel generator and the AC loads which are connected to a common AC transport. The bus connection of two microgrids are coordinated through equal associated bidirectional power converters, called interlink power converters. In any case, there are some specialized difficulties in resembling power converters in crossover microgrids. The Flexible AC transmission System (FACTS) gadgets have additionally been utilized to control power stream in AC transmission frameworks. In the current paper, utilizing UIPC is acquainted with control the traded power between microgrids just as fundamental lattice in a mixture microgrid.

2. BASIC BLOCK DIAGRAM AND COMPONENTS

The power source unit contains a transformer, a bridge circuit, a filter and a regulator. The filter is used to remove the ripples in the supply. The regulator makes the supply voltage constant.

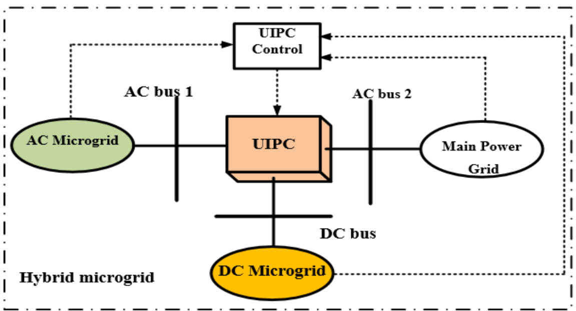

Fig.1 Block Diagram

3. UIPC AND ITS CONTROLS

3.1. Conventional UIPC

The UIPC model has the phase-shifting transformers of the interphase power with voltage source converters (VSCs). Subsequently, two AC transports, for example $V1$ and $V2$, are associated through three VSCs, for example VSC1, VSC2, and VSC3, in each stage. VSC1 and VSC2 go about as stage moving converters while VSC3 goes about as voltage controlling converter. VSC1 works in inductive mode and infuses the arrangement voltage $VseL$ to the line through transformer T1. Conversely, VSC2 works in capacitive mode and infuses the arrangement voltage $VseC$ to the line through transformer T2. The third VSC, for example VSC3 is associated with one of the AC transports, here $V1$, through transformer T3 and controls the AC voltage. The DC transport of all the VSCs is associated in equal and provided by a steady capacitor. In this manner, the DC connect voltage VDC is liable for giving dynamic forces of each VSC. Along these lines, through stage point control of VSC1 and VSC2, the traded power between the two AC transports would be controlled.

3.2. Proposed UIPC

The modified UIPC will be shown in the subsequent subsection. The regular construction of UIPC illustrated, has the following deficiencies: Each phase implements three VSCs; therefore, to connect three phases of AC buses, one needs nine VCSs, and also nine power transformers which make the topology extensively costly.

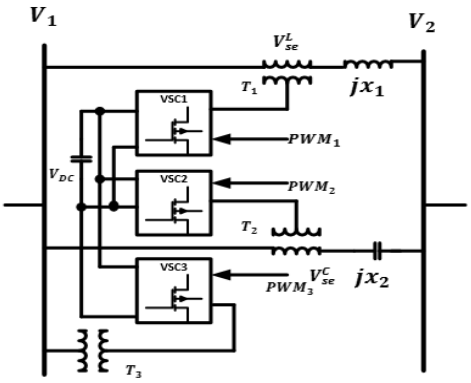

FIG .2 Conventional structure of UIPC; each phase implements three power converters

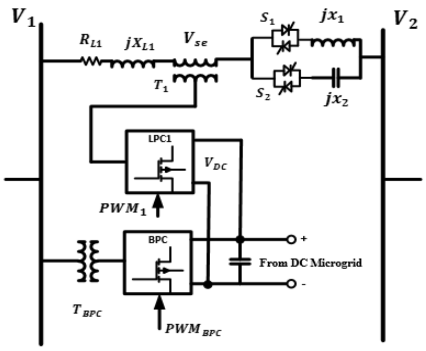

FIG.3 Proposed topology of UIPC (each phase implements only one power converter, named as LPC)

The DC connections of all the VSCs in each stage are related in equal. Nonetheless, as portrayed, the VSCs with shared DC joins are convinced to make the common DC interface voltage oscillatory when the efficiency of VSCs change or when there is a difficulty on the plan model, for instance, change in a framework. The DC interface

voltage variety is a central worry in VSCs with a typical DC connects. This issue has not been thought of. To eliminate the previously mentioned barriers, the altered UIPC model is proposed as shown. As appeared, each stage simply utilizes one force converter, named as $LPCj$, where $j\in\{1,2,3\}$ is the line number. These power converters, through transformers Tj, inject the series voltage $V_{se}\angle\ \varphi_{se}=V_{se}r+jV_{se}i$ to each line, where $V_{se}r$ and $V_{se}i$ are the real and imaginary parts of injected series voltage, respectively. The line impedance is $Z_Lj=R_Lj+jX_Lj$.

$V_{se}=K_AV_{DC}\angle\ K_P\varphi_{se}$ (1)

Where, K_A and K_P are voltage and phase coefficients, respectively. The voltage sufficiency coefficient KA is for sure an element of heartbeat width balance (PWM) approach and the stage coefficient KP is ±1 and φse is generally equivalent to $\pi 2$.

The switches $S1$and $S2$are against equal thyristors and would be composed by the infused voltage stage point through the control framework. At every moment, just one of these switches conducts at each stage, contingent upon the stage point sign.

At whatever point the voltage stage coefficient KP is equivalent to +1, the UIPC is in the inductive mode (IM) and $S1$ is on while $S2$ is off. Along these lines, when the stage coefficient KP is equivalent to - 1, the UIPC is in the capacitive mode (CM) and $S1$ is off while $S2$ is on. In this manner, the traded power between the two AC transports, for example $V1$ and $V2$, can be controlled. In Fig. 3,

Additionally notice that here is just a single BPC for all stages. The DC transport of this BPC is then associated with the DC microgrid. The BPC, through transformer $TBPC$, is likewise associated with one of the AC transports (more fragile AC transport, for example AC microgrid transport), here $V1$, to direct the AC voltage and give power trade the DC microgrid. According to vector diagram one may obtain;

$\varphi_{se}L=\varphi 1+\alpha 1$ (2)

$\varphi_{se}C=\varphi 2+\alpha 2$ (3)

These angles are calculated by considering different operation modes of the UIPC, i.e. IM or CM. The exchanged power between the two AC buses would be determined as follows:

$S=V_2((V_1-V_2)^*/Z_L)=$ (4)

$(V_2\cos\delta_2+jV_2\sin\delta_2)(V_1\cos\delta_1+jV_1\sin\delta_1-V_2\cos\delta 2-jV_2\sin\delta_2)^*/(RL_1-jXL_1)$

where, $\delta 1$and $\delta 2$ are the phase angles of the voltages V_1 and V_2, respectively.

After some mathematical manipulations, Equation (4) can be rewritten as follows:

$P=RL_1V_1V_2(\cos\delta_1\cos\delta_2+\sin\delta_1\sin\delta_2+RL_1V_{22})-XL_1V_1V_2(\cos\delta_1\sin\delta_2-\sin\delta_1\cos\delta_2)/(RL_{12}+XL_{12})$ (5)

$Q=RL_1V_1V_2(\cos\delta_1\sin\delta_2-\sin\delta_1\cos\delta_2)+XL_1V_1V2(\cos\delta_1\cos\delta_2+\sin\delta_1\sin\delta_2+XL_1V_{22})/(RL_{12}+XL_{12})$ (6)

In microgrids, $RL_1\gg XL_1$ and we get:

$P=V_1V_2(\cos\delta_1\cos\delta_2+\sin\delta_1\sin\delta_2+RL_1V_{22)/}RL_1=(V_1V_2/RL_1)(\cos(\delta_1-\delta_2)+RL_1V_{22})$ (7)

$Q=V_1V_2(\cos\delta_1\sin\delta_2-\sin\delta_1\cos\delta_2)/RL_1=(V_1V_2/RL_1)\sin(\delta_2-\delta_1)$ (8)

Thus, the transferred active power is varied by the voltage magnitudes of the AC buses whereas the reactive power is varied by the phase angle difference.

The voltage magnitude and phase angle difference are controlled by the proposed UIPC implying that the exchanged active and reactive powers between two AC buses would be controlled easily.

The control framework incorporates two subsystems: Series VSC control and NDO-MS-SMC based DC connect control. The Series VSC Control subsystem controls the infused voltage and switches $S1$and $S2$ and an ideal H∞ based fluffy rationale regulator is sent its design.

This control subsystem is portrayed in the ensuing subsection. The SMC based DC connect Control subsystem is answerable for balancing out the common DC interface voltage vacillations and depends on another unsettling influence spectator based hearty different surface sliding mode control procedure. This control plan technique is depicted in the following segment.

Momentarily, in contrast with the traditional construction, the proposed UIPC geography has the accompanying benefits;

- Each stage just necessities one LPC.
- Only one BPC is needed in the three-stage structure. Subsequently, the general model necessities four VSCs and three force transformers.
- The DC interface voltage is provided through the DC microgrid. This element empowers the UIPC to interconnect the AC and DC microgrids.
- An ideal fluffy rationale regulator is conveyed in the control construction of the LPCs which diminishes the mistakes.
- The voltage changes of the DC interface are damped utilizing an unsettling influence spectator based strong different surface sliding mode control approach which is portrayed in the following segment.

3.3Control strategy for LPCs

The proposed control conspire for the proposed UIPC structure incorporates two control subsystems; LPCs control methodology and SMC based control plot for BPC. These control subsystems have control communications also. Fig. 4 shows the arranged control approach for each LPC at each stage. As appeared, the infused arrangement voltage and the line current are estimated and scaled.

At that point, to acquire the central parts of these scaled signs, a band pass channel is utilized. The boundaries (move work) of this channel are resolved utilizing MATLAB , as follows:

$Tf=190.10ss2+190.10s+145321$ (13)

The root mean square estimations of the sifted signals are then gotten. The infused voltage mistake is indicated to the proposed ideal fluffy rationale regulator (FLC). The period of the infused voltage is estimated utilizing a PLL.

At that point, the indication of this stage, which is really KP in Equation (1), is resolved and dependent on this sign, it is presumed that the UIPC works whether in IM mode or CM mode. Consequently, the fitting stage move is applied; $+\pi 2$ for IM mode and $-\pi 2$ for CM mode.

Besides, the switches $S1$ and $S2$are empowered/handicappedn dependent on the activity modes. The ideal FLC is planned dependent on H∞ sifting plan methodology which has completely been portrayed and approved in by the creators of this work. As delineated, a DC connect voltage signal is taken care of to the all LPCs control framework for coordination. The blunder signal is then given to an ideal FLC. Subsequently, the control signal (reference) for execution in PWM unit is produced utilizing these signs. In view of the PWM conspire, the abundancy of the infused voltage (through KA) is controlled, as given in Equation (1).

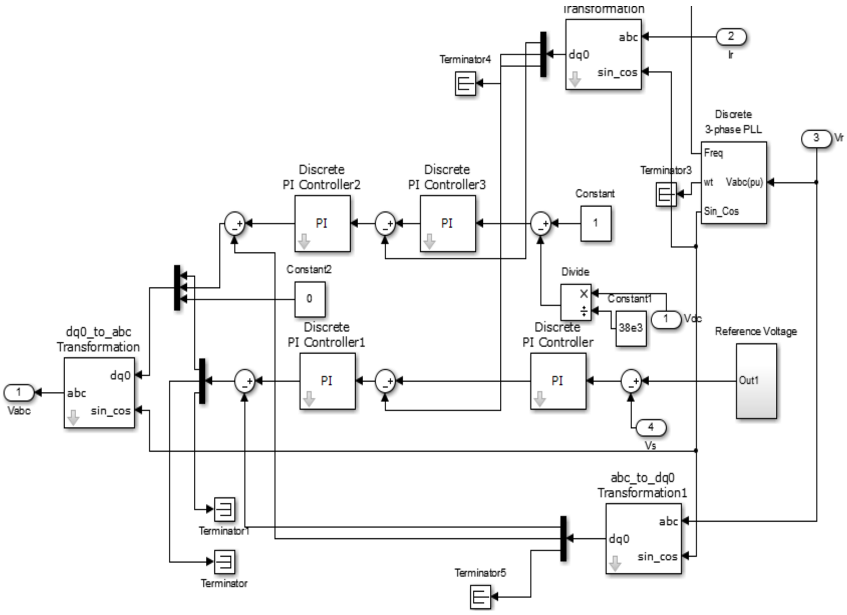

FIG.4 Planned control strategy for LPCs

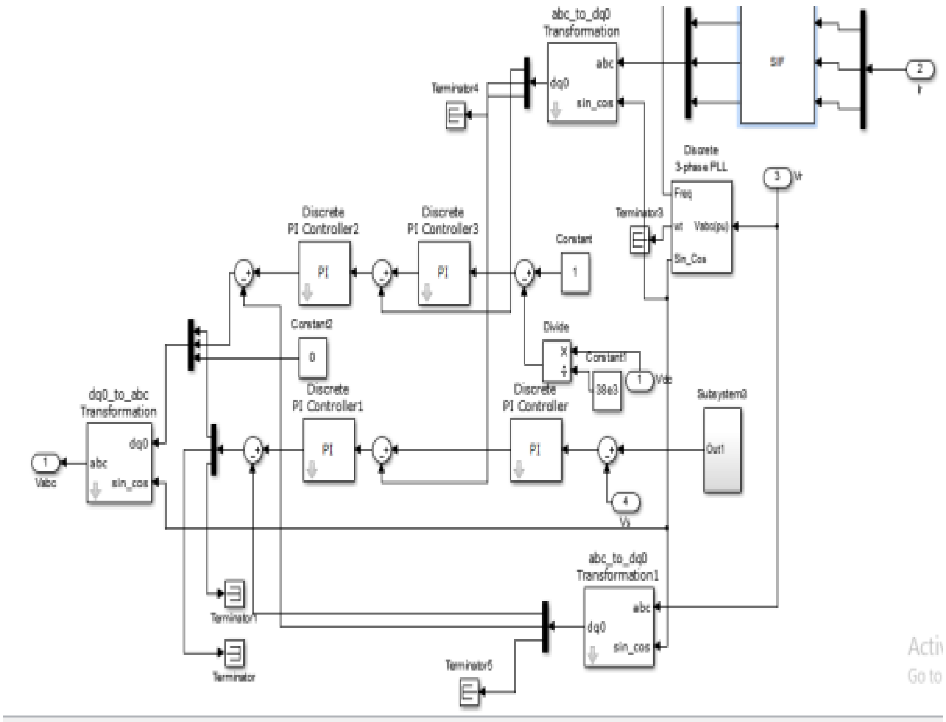

FIG.5 Control of DC link of BPC based on new NDO-MS-SMC strategy

3.4. PROPOSED CONTROL OF UIPC

The DC connections of the LPC and BPC are in equal and associated with the regular DC transport of the DC microgrid. As referenced previously, the DC connect voltage would be insecure because of the yield dynamic force change of force converters, burdens or PV framework in the DC microgrid. Consequently, another NDO-MS-SMC is utilized in this part to control the DC connect voltage of the proposed UIPC.

The BPC is dependable to manage the DC connect and in this manner, the proposed NDO-MS-SMC system is applied to the BPC. As introduced in Fig. 5, the proposed control plot incorporates three sections: 1-the voltage control circle 2-the current control circle and 3-the NDO. The NDO is liable for assessing the vulnerabilities and force changes in the DC microgrid.

Besides, the NDO cooks a reference signal for the dead-time remuneration unit and the current control circle. The voltage control circle utilizes ideal corresponding fundamental (PI) regulators joined by the feedforward power unsettling influence to get up to speed the protected postpone settled in the elements of the current control circle and the proposed aggravation onlooker. The PI regulators in both current and voltage control circles are ideally tuned utilizing the genetic algorithm.

4. Simulation Results and Discussion

4.1.Validation of main grid

The proposed UIPC is contrasted with the regular UIPC appeared in Fig. 3 to confirm the proposed structure and further its adequacy over the ordinary geography. To this end, the UIPCs boundaries are equivalent to those given. The AC microgrid is associated with principle lattice through a 2 km dispersion line with impedance of RL=0.01ω,=5mH per stage. The force stream among the main matrix and the microgrid is dissected. Initially, the traditional UIPC is carried out to control the traded power between them.

The control frameworks reactions are delineated. Fig shows that the customary UIPC construction and its control methodology acquainted are capable with roughly follow the predefined reference signal though demonstrates that the proposed UIPC can suitably follow the reference signal created by the proposed control framework. These figures show that the proposed control methodology carries on gentler for genuine force frameworks. Shows the traded power control execution when the regular UIPC and the proposed UIPC are carried out.

At first, the framework is in the consistent states and the UIPC is impaired and in this manner, no arrangement voltage is infused. In the AC microgrid, just one of the diesel generator units is empowered and there are 165 kW AC/DC loads associated with the normal AC transport in this microgrid. The breeze turbine at first is additionally incapacitated. The DC microgrid doesn't have to import power since 300 kW complete burdens (which is equivalent to the all out PVs age and ESS power) is associated with its regular DC transport. The AC microgrid is considered here as a feeble framework.

Hence, the AC side of the BPC is associated with this microgrid. The AC microgrid gets 115 kW from primary force framework until t = 0.2s when one of the diesel units is empowered, as appeared. Consequently, the UIPC goes to the inductive mode and 0.065 pu arrangement voltage is infused into the dissemination line. Accordingly, the traded power is diminished to around 65 kW, and keeps this worth until t = 0.6s when the other diesel units and the breeze turbine are empowered.

Along these lines, the UIPC changes to the capacitive mode and infuses 0.063 pu arrangement voltage to the circulation line and likewise, the traded power (supreme worth) scopes to 185 kW which is given to primary matrix. Fig. 13 shows the age in each microgrid. Clearly the ordinary UIPC structure with too many equal associated power converters acts oscillatory though the proposed UIPC and its control technique can easily move power between the half and half microgrid and utility.

As per Fig, the settling time for the regular UIPC is around 4s though this incentive for the proposed UIPC is under 2s, for example over half quicker than the customary UIPC. The overshoot when the ordinary UIPC is carried out is about 37.14% though there is no any overshoot when the proposed UIPC is executed.

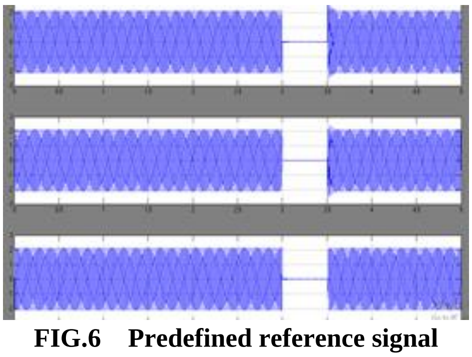

FIG.6 Predefined reference signal

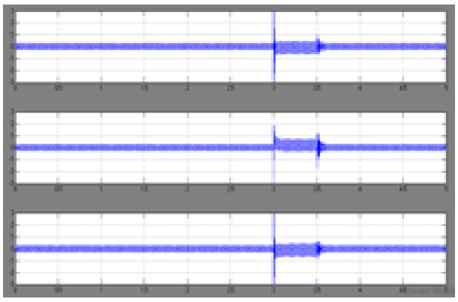

FIG.7 Reference signal tracking performance

4.2.Power flow control from DC microgrid to AC microgrid

The power stream execution from the DC microgrid to the AC microgrid is broke down to check the leader activity of the proposed UIPC. As demonstrated, the DC connection of the proposed UIPC is went with to the DC microgrid and this is one of the fundamental highlights of the proposed structure. The DC connection of the BPC is then controlled utilizing the proposed NDO-MS-SMC methodology outlined.

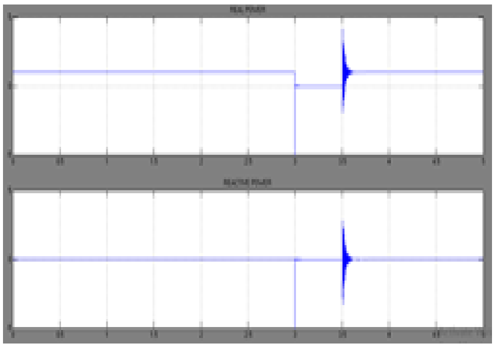

FIG.8 Exchanged power control between two AC microgrids

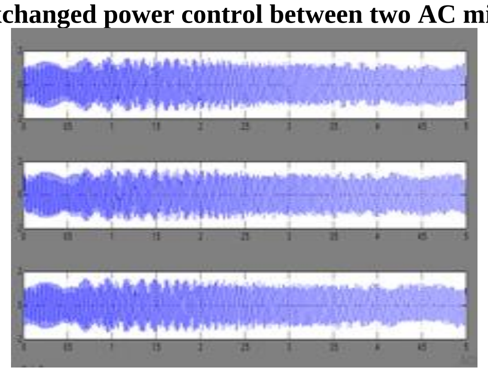

FIG.9 Generation in each microgrid

Maintaining the exchanged power constant between the AC microgrid and main grid, as illustrated, 40 kW is demanded by the AC microgrid at t = 0.42s. The internal consumption in the DC microgrid is 240 kW. Thus, the DC link active power increases to 280 kW to supply the AC side. The DC link voltage at this condition is demonstrated. Obviously, the proposed NDO-MS-SMC strategy is able to overcome the problem of voltage fluctuations.

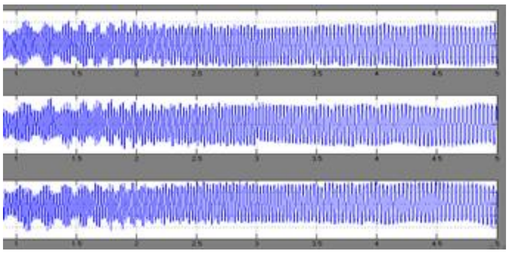

FIG.10 Active power of DC link when 40 kW is demanded from the AC side

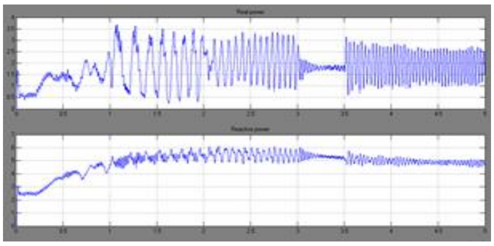

FIG.11 DC link voltage when 40 kW is demanded from the AC side

4.3.Disturbance rejection performance and stability proof

To check the stability and rejection of dismissal execution, the time variable sign is considered as inconvenience on the plan model. This aggravation is *IL*, the lumped DC loads current. Additionally, 10% changes in the AC side voltage is likewise applied. The soundness of the DC connection of the UIPC is the primary worry in such circumstances. The reproduction results for the proposed UIPC and the traditional UIPC are appeared. As appeared, the traditional UIPC brings numerous motions with extremely high overshoots though the proposed UIPC outfitted with the new control technique has better execution and keeps the framework steady also.

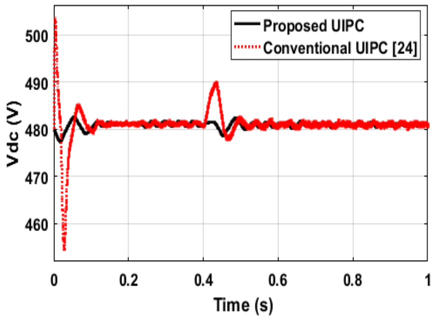

FIG.12 Executive action of the proposed UIPC when there are disturbances on the scheme model

5. Conclusion

The hybrid microgrid structure is the most likely alternative in the forthcoming smart circuits to assemble the sustainable assets as AC/DC loads. This is because of the way that this construction has the benefits of both AC and DC microgrids at the same time. One customary issue with this construction is the force trade control among interconnected AC and DC microgrids. In this examination, a UIPC based arrangement has been proposed as a better option than the equal associated power converters which have brought numerous issues. A changed construction of the UIPC has initially been proposed and afterward viable control methodologies have been presented for the adjusted UIPC. The recreation results approved the changed model notwithstanding the force trade control execution among AC and DC microgrids.

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