AN APPROACH OF A DEEP REINFORCEMENT ALGORITHM BASED CONTROL FOR A MATRIX CONVERTER OPERATING ON UNBALANCED GRID VOLTAGES CONDITION

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Abstract: The approach of a control algorithm for a matrix converter that uses unbalanced grid voltages is presented in this research. Without the requirement for a DC link, direct power conversion between AC sources of various frequencies and phases is possible when a matrix converter is used. However, maintaining the balance of the output voltages and currents when using a matrix converter on unbalanced grid voltages poses serious difficulties. With the help of a variety of characteristics, such as space vector modulation, a reference frame transformation, and a compensation method, the suggested control algorithm resolves these problems. A novel Matrix Converter Control - Deep Reinforcement (MCC-DR) has also been created, and it possesses the necessary characteristics and processing steps. Studies using simulations have shown that the suggested control algorithm is effective at preserving output voltage and current balance even when there is a significant imbalance in the grid voltages. This method opens the door for the use of matrix converters in a wider range of applications, which is a significant advancement in the field of power electronics. Furthermore, Matlab is used to implement the proposed system. Therefore, the proposed work performance can be the output voltage and current waveform to speed control.

Keywords: DC voltage, Matrix converter, Power switches, unbalanced grid voltage, high power density

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1. Introduction

Without using a DC-link in the middle, matrix converters convert electricity from AC to AC directly [1]. One of the key benefits of the matrix converters that enable a small design is the absence of reactive components in the DC-link. The matrix converters also offer sinusoidal input currents, four-quadrant operation, and adjustable input power factor. As a result, this topology has drawn a lot of interest because it offers a desirable option to intermediate-stage topologies [2]. The requirement for nine bi-directional power switches, which equals 18 IGBTs and 18 diodes, is the primary drawback of matrix converters. The matrix converters will also be susceptible to disturbances in the input voltages because these will transmit to the output side due to the absence of internal energy storage components [3]. Since the matrix converter converts frequencies directly, imbalances on the utility side can instantly be reflected on the load side and cause the system to produce undesirable input/output harmonics [4]. There have been several documented methods to lessen the impact of source voltage unbalance for the traditional matrix converter. The exhibition of two potential unbalance control systems when the source voltage just incorporates positive and negative succession parts is combined by this uneven voltage among them [5]. The first method offers the same order for the incoming voltage and current vectors. The second reduces load side voltage deterioration while optimising line side current distortion [6].

When creating current modulation systems, sinusoidal and balanced input voltages are typically taken for granted [7]. In this case, detecting the zero crossing of a single input voltage is sufficient to synchronize the control algorithm with the input voltage system [8]. Sadly, when lopsided stockpile voltages are available, these strategies prompt low request sounds to appear in the result voltages [9]. It is not balanced for the voltages at the input [10], adjusted and sinusoidal result voltages can be created by observing the quick worth of two line-to-line input voltages [11]. It is extremely likely that the information/yield power balance condition can be used to demonstrate that non-sinusoidal information flows will manifest in this scenario [12]. Logical estimations have been made under various working settings to decide the restrictions of the voltage move proportion and the information current consonant substance [13]. Additionally, it has been shown that the matrix converter's input current modulation approach significantly affects the input current's harmonic content. [14]. When operating a matrix converter on an unbalanced grid voltage, there can be an imbalance in the power flow [15], which can result in increased voltage and current stresses on the converter's components [17]. This can lead to decreased reliability and a higher risk of component failure. Several methods was implemented to solve these issues bidirectional interlinking converter [18], Point of Common Coupling [19], and Bi-directional DC-DC converter [20], but no such solutions were found. Thus, a novel technique has been introduced in this paper.

2. Related works

Some of the recent related research areas are described below,

As of the shortfall of a dc-interface energy capacity part, the information and result exhibitions of the framework converter (MC) are incredibly delicate to the lopsided lattice conditions. Therefore, Xiong *et al*. [21] have proposed finite-control set model predictive control (FCS-MPC), In order to lessen the negative consequences of uneven grid voltages, this research suggests a simple and effective control technique based on the finite-control set model predictive control. (FCS-MPC). Decomposition of the positive and negative sequences is also prevented, which is complicatedThe inconsistent exchange recurrence of restricted control set-model prescient control (FCS-MPC) is a negative because it is dependent on the testing time frame and working point.

It may not be enough for basic signal generators that require a considerable correspondence delay because the majority of IoT devices don't reply well. Therefore, Krishnan *et al*, [22] have proposed Robust Grid Unbalanced Control (RGUC) Using simulation and hardware results, Robust Grid Unbalanced Control's effectiveness was confirmed and this suggested control method obtained an overall efficiency of 98.53%. Additionally, this RGUC-based matrix converter stays implemented using a cheap but capable FPGA, and the findings of the experiment are contrasted with those of the simulation. Practically speaking, integrating IoT innovation with current networks continues to be a significant challenge.

Because they must be grid-friendly, indirect matrix converter (IMC) uses require unity grid power factor. Therefore, Gong *et al*, [23] have proposed Low-Cost Phase-Angle Compensation, In this study, a low expense stage point remuneration system is suggested. However, the advantages of being load-range-compatible and parameter-adaptive to the system are not realized. The shut circle matrix power factor control strategies presently being used ordinarily have complex designs, bringing about costly equipment and programming necessities.

On a model that has been created, the presentation of the proposed techniques has been tentatively tried under states of variable sun powered insolation, uneven stacking, and different network unsettling influences like stage irregularity, consonant bending in the matrix voltage, and so forth.. Therefore, Kumar *et al*,[24] have proposed Normalized Laplacian Kernel Adaptive Kalman Filter (NLKAKF), The main goal of the proposed NLKAKF control was to use generated solar PV power to satisfy the loads' active power requirements. The grid receives any excess power after the loads have been fed. NLKAKF control, on the other hand, uses additional lattice power when delivered PV power falls short of the necessary burden power. The grid's power quality improves during this process.

Rotating vectors are used because there is no common-mode voltage produced by them.Terefore, Deng *et al*. [25] have proposed Matrix Converter - Direct Torque Control (MC-DTC), To decrease well known mode voltage, another immediate force control (DTC) is recommended for an extremely durable magnet simultaneous engine (PMSM) drive framework took care of by a network converter (MC). Rotating vectors are employed since they result in a common-mode voltage of zero. The advantage of the suggested MC-DTC method is that it is a realistic and simple method for making a multidimensional switching table for rotating vectors. Through trials, the proposed MC-DTC's adequate dynamic and steady state performance as well as a significant decrease in common-mode voltage were shown.

The ongoing shut circle matrix power factor control techniques commonly have unpredictable designs, requiring high equipment and programming necessities. Therefore, Gong *et al.* [26] have proposed low-cost phase-angle compensation, In order to save expenses, this research suggests a low-cost phase-angle compensation technique. However, the advantages of adapting to framework boundaries and being suitable for a wide range of loads remain. According to simulation and experimental study, the suggested method's steady-state and dynamic-state compensation works well under a variety of load scenarios.

Be that as it may, this paper talks about and resolves unexpected issues with safe substitution and tweak because of the presence of medium recurrence transformers in every cell. Therefore, Nasir *et al*, [27] have proposed Modular Isolated Matrix Converter (MIMC), For footing applications and upcoming conveyance networks with constrained area for low voltage (LV) or medium voltage (MV), the MIMC geography is an appealing single-stage high power thickness ac converter. Since the result recurrence was fixed to the information recurrence, there would just be a predetermined number of utilizations for a solitary cell. The MIMC geology, a solitary stage AC converter with a powerful thickness, is valuable for traction applications and future transmission networks with restricted space for low voltage (LV) or medium voltage (MV).

The critical commitment of this paper is given as follows:

- ✓ Initially, the voltage is given as input to the matrix converter.
- ✓ Here, a novel Control-Deep Reinforcement algorithm was designed in the system to regulate the speed of the DC motor.
- ✓ The matrix converter maintains the load on a DC motor by using a C-DR algorithm system that adjusts the output voltage and current waveform to speed control.
- ✓ The fluctuations in the DC motor are removed by the proposed C-DR algorithm and the performance are evaluated.
- ✓ Finally, the outcome has been validated with other models in terms of and execution time and Total Harmonic Distortion (THD)

3. System model and problem statement

Matrix converter (MC) is a type of power electronic converter that is capable of directly converting AC voltage without requiring any intermediate DC circuit. It uses a matrix of semiconductor switches to connect the input AC voltage directly to the output AC voltage. This makes the matrix converter an attractive solution for applications where traditional converters cannot be used due to size or cost constraints.

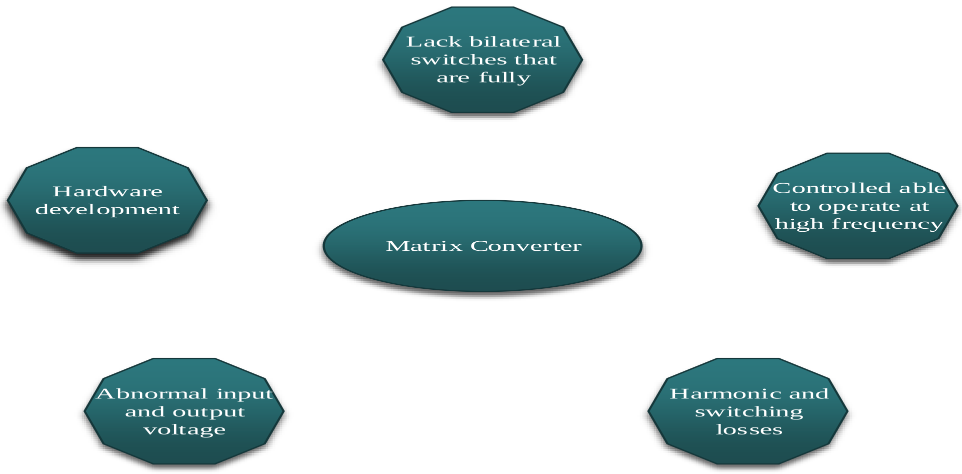


Figure 1. System model of matrix converter

When operated on an unbalanced grid voltage, the matrix converter faces some challenges due to the presence of unbalanced voltages and currents. imbalanced power flow can result from imbalanced voltage, increasing voltage and current strains in the converter. This can result in a decrease in the converter's efficiency, as well as an increase in the risk of component failure. These challenges has been motivated to do this research work.

4. Proposed Methodology

Matrix converters are power electronic devices that can convert AC power from one voltage level to another without the use of bulky transformers. Here, a novel Control-Deep Reinforcement algorithm is used for the matrix converters operating on unbalanced grid voltages to produce the output voltage. The matrix converter receives its input as the unbalanced grid voltage. The matrix converter maintains the load on a DC motor by using a C-DR algorithm system that adjusts the output voltage and current waveform to speed control. Finally, the matrix converter uses its matrix arrangement to convert the input voltage to an output voltage that is suitable for the connected load. In terms of Total Harmonic Distortion (THD) and execution time, the result has been validated with other models.

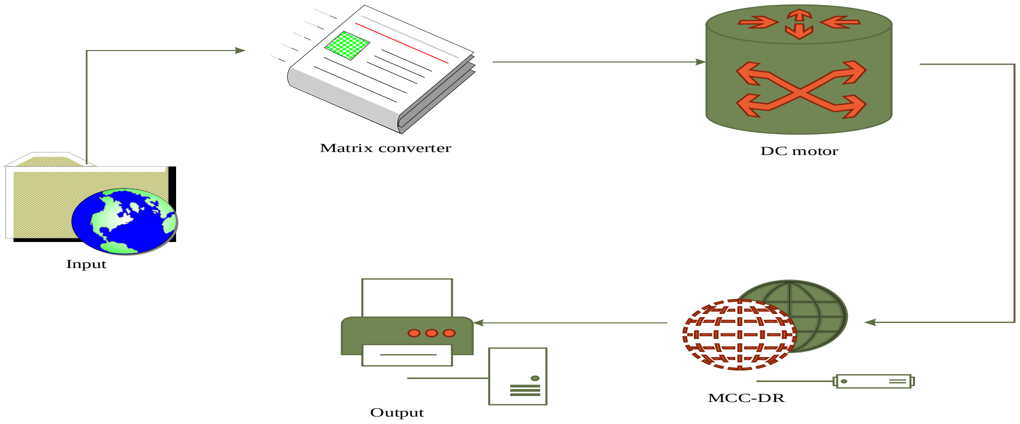


Figure 2. Proposed methodology

Initially, the voltage is given as input to the matrix converter. Here, a novel Control-Deep Reinforcement algorithm was designed in the system to regulate the speed of the DC motor. The matrix converter maintains the load on a DC motor by using a C-DR algorithm system that adjusts the output voltage and current waveform to speed control. The fluctuations in the DC motor are removed by the proposed C-DR algorithm and the performance are evaluated. Finally, the outcome has been validated with other models in terms of Total Harmonic and execution time.

4.1.1. Design of MCC-DR

In this research paper we have integrating two effective methods such as Matrix Converter Control (MCC) and Deep Reinforcement(DR) to done without requiring a lot of storage.

4.1.2. Sinusoidal Grid Currents

When grid voltage is unbalanced, there are two standard methods for obtaining sinusoidal grid current. One purposes a shut circle regulator to control the info current without utilizing lattice voltage parts, while the other tweaks the heading of the info current vector by utilizing positive and negative succession matrix voltage parts. The course of the info current vector was recently credited to that of a regulation vector, which is characterized as:

$$\psi^* = V_p^* e^{j\omega t} - V_n^* e^{-j\omega t} \quad (1)$$

Where, ψ^* indicates modulation vector, V_p^* and V_n^* positive, negative voltage, $e^{j\omega t}$, $e^{-j\omega t}$ indicates exponential function.

4.1.3. Matrix converter

The MC empowers direct change between the air conditioner input supply and the ideal AC yield voltage. It is an air conditioner AC converter comprised of nine bidirectional switches. The architecture of MC is simpler than that of the standard AC-DC-AC method. Employing MC also has the advantage of providing input and output in sinusoidal waveforms. Nine bidirectional switches make up the MC, which enable connection from all input lines to all output lines. Aside from that, an indirect matrix converter provides a lot of benefits over direct matrix converters. The inverter stage and the rectifier stage are the two phases that make up a roundabout grid converter (IMC).

Network converters, which are immediate ac/ac power change gadgets, can create variable voltages at their result terminals concerning recurrence and abundancy without the utilization of weighty electrolytic capacitors with short life expectancies. The plan of high unwavering quality, high power thickness converters is made conceivable by this pivotal attribute.

$$\bar{J} = J^+ e^{i(k_j t + \varphi^+)} + J^- e^{i(-k_j t - \varphi^-)} \quad (2)$$

J^+ and J^- are the peak values of the positive and negative sequences of the line currents; φ^+ and φ^- are their initial phase angles, $\bar{J}$ indicates matrix converter, $e^{i(k_j t + \varphi^+)}$, $e^{i(-k_j t - \varphi^-)}$ is exponential function

4.1.4. Unbalanced Grid Voltage

A three-stage unequal lattice voltage framework without a zero succession can be addressed as the amount of the positive and negative grouping parts in a fixed reference outline so that

$$\bar{F} = F^+ e^{ik_j t} + F^- e^{i(-k_j t - \theta^-)} \quad (3)$$

Where, F^+ & F^- are the peak values of positive and negative sequence components of the grid voltage, θ^- is initial phase angle of the negative sequence, k_j is the angular frequency, $e^{ik_j t}$, $e^{i(-k_j t - \theta^-)}$ is exponential function, $\bar{F}$ indicates unbalanced grid voltage.

4.1.5. DC Motor

A DC motor is an electrical device that converts electrical energy into dynamic energy. A DC generator generates mechanical rotation using electrical energy.

4.1.6. Maximum Voltage Transfer Ratio

First of all, we should anticipate that the load side converter will function as an inverter that converts electricity from a stable dc source to a standard voltage source.

The connection between the sufficiency of the key part of the result voltage and the dc source voltage is characterized by the inverter tweak file MI. This intends that

$$V^*_o = MI \frac{V_{dc}}{2} \quad (4)$$

Where, MI represents inverter modulation index, V_{dc} indicates dc voltage, V^*_o indicates output voltage.

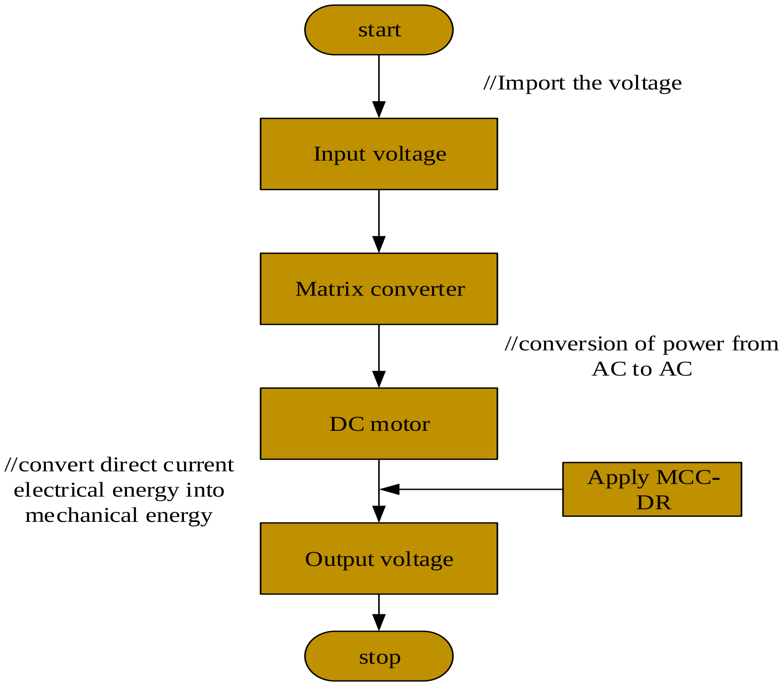


Figure 3. Flow chart of proposed MCC-DR

4.1.7. Matrix Converter Control

Electronic power converters called matrix converters change the shape of electrical energy. In contrast to conventional converters like rectifiers or inverters, matrix converters convert AC power to AC power using a matrix of controlled switches without a DC-link storage device in between.

The switching patterns of the semiconductor devices (usually insulated-gate bipolar transistors, or IGBTs) within the matrix must be modulated in order to control a matrix converter as shown in Fig.4. The goal is to minimize distortion and maximize efficiency while achieving the necessary conversion from the input AC waveform to the output AC waveform.

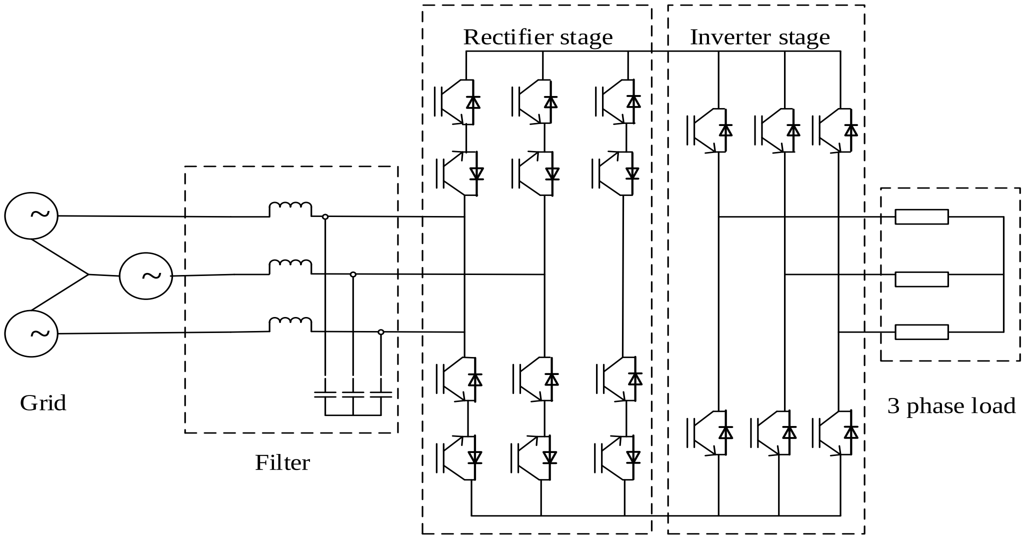


Fig.4.Scematic diagram of Matrix Converter

4.1.8. Deep Reinforcement

They show a general DR in this section that can be used to solve challenging problems with DC-motor changes. The DR method consists of two phases: an offline phase for building deep neural networks (DNNs) and an online phase for deep Q-learning.

5. Result and Discussion

The experimental design and the proposed method's efficacy are discussed in this section. The system's success is assessed using a variety of metrics, including total harmonic distortion, exection time with the aid of optimization and reinforcement networks. The parameter description is tabulated in table 1.

5.1.1. Performance metrics

To validate our proposed Alternating optimization-Deep neural network (AO-DNN) model the performance metrics are evaluated in standings of Total Harmonic Distortion, Execution Time, and Settling time.

5.1.2. Execution Time

The execution time of a matrix converter refers to the amount of time needed to finish processing a certain set of input data. It is influenced by elements including the size of the incoming data, the computing capability of the hardware, and the complexity of the matrix converter method.

5.1.3. Settling Time

On the other hand, settling time describes the amount of time needed for the matrix converter's output to stabilize within a reasonable range following a change in the input or load conditions. It is influenced by things including the system's dynamics, the control method used, and the power electronic devices' response time.

A thorough investigation of the topology, control strategy, and system dynamics of the particular converter is needed to identify the precise equations for execution time and settling time in a matrix converter. There may be different equations for execution time and settling time depending on the control schemes and matrix converter designs used.

5.1.4. Total Harmonic Distortion

If you somehow happened to inspect the sign with an oscilloscope, the recurrence that you would have the option to distinguish is the central recurrence, otherwise called the fundamental recurrence of the sign. THD is defined as the ratio of the root mean square (RMS) voltage of the major repeat to the RMS voltage of each and every symphonious repeat (from the second consonant on).

$$THD^* = \frac{\sqrt{\sum^{*\infty}{}_{m=2} V_{m\_rms}{}^{*2}}}{V^*{}_{fund\_rms}}$$

Where, $V_{m\_rms}{}^{*2}$ is the RMS voltage of the mth harmonic and $V^*{}_{fund\_rms}$ is the RMS voltage of the fundamental frequency

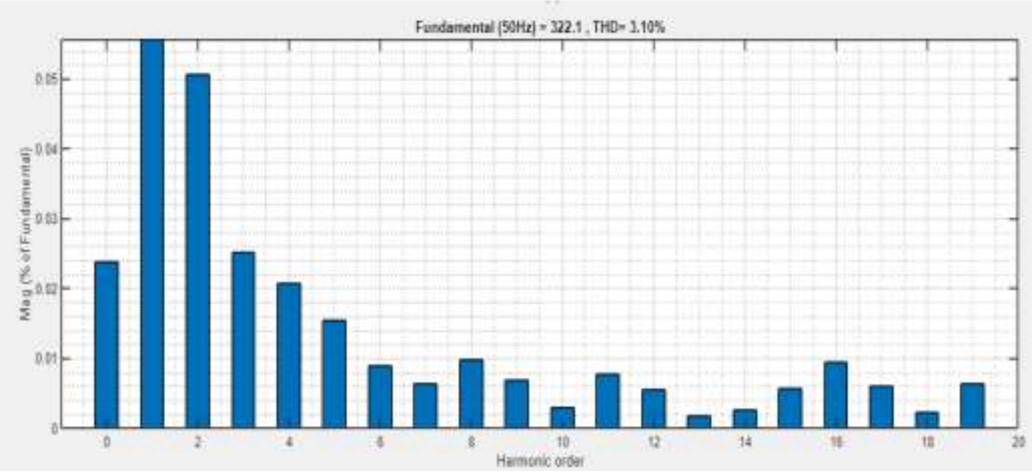


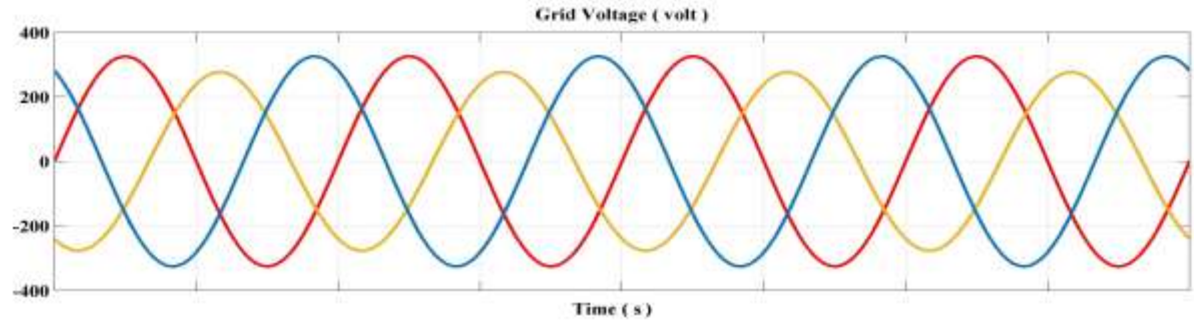
Figure 4. Proposed model of Total Harmonic Distortion

5.1.5. Simulation Result and Analysis

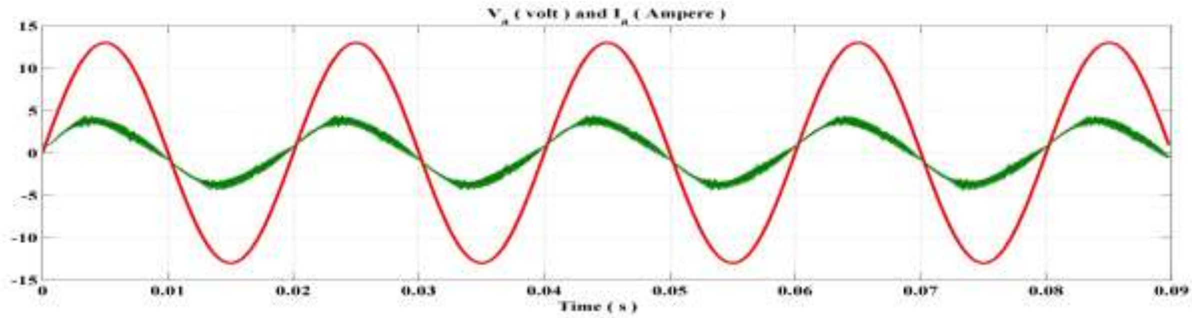
The proposed control strategy for operating the IMC is tested under MATLAB/Simulink and its performance is compared with the existing controller to show its efficiency. The specification of the implementation parameter is tabulated in table 1. The presented design was executed in MATLAB software, and the outcomes are estimated. Here, the results are evaluated in dual cases to check the robustness of the presented approach. Moreover, a comparative analysis was performed to validate that the developed model achieved better results than other existing approaches.

Table 1: Parameter Settings

Parameter	**Value**
Supply line voltage	200 V
Source frequency	50 Hz
Voltage Transfer ratio	0.8
Load frequency	50 Hz
Input filter capacitance	21.5μF
Input filter inductance	4mH
Input filter resistance	0.5Ω
Load inductance	60mH
Load resistance	**100Ω**
Sampling period	200μs
Sampling rate	7.5 kHz



(a)



(b)

Fig.5 (a) displays the magnitude unbalanced 3-ϕ grid voltage and Fig.(b) shows a - phase scaled grid voltage (v_a) and (i_a) under magnitude unbalanced three - phase grid voltage.

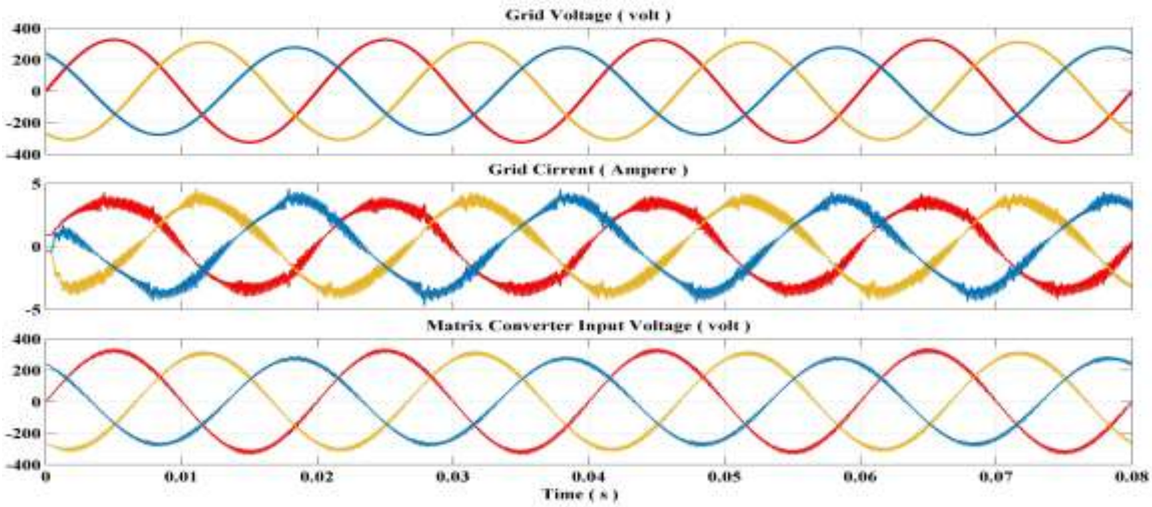
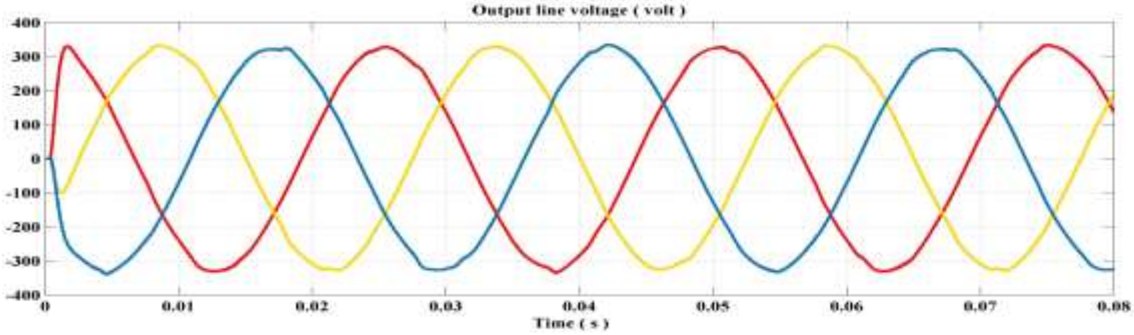
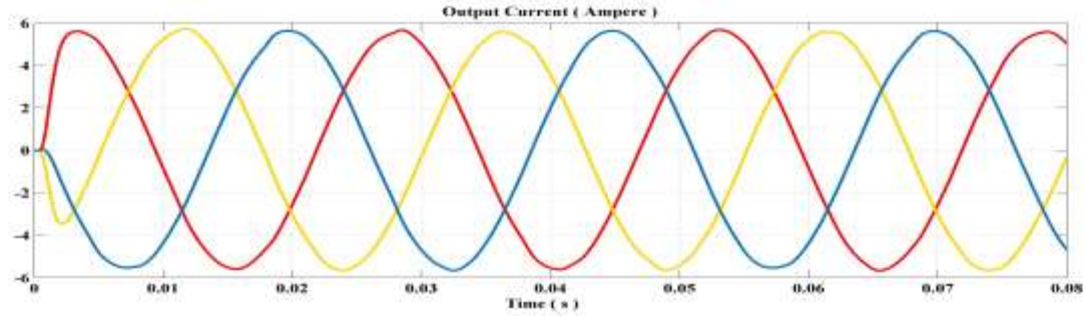


Fig.6: shows the magnitude of unbalanced three-phase grid voltages, Grid phase current and Matrix converter input phase voltages.



(a)



(b)

Fig.7 (a)display the matrix converter output line voltage under magnitude un-balanced three - phase grid voltage and Fig.(b) shows matrix converter output line current under magnitude unbalanced three - phase grid voltage

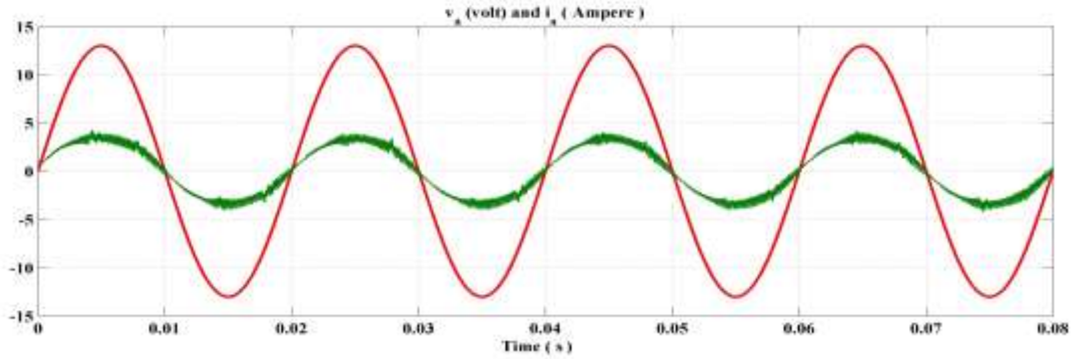


Fig.8 shows a - phase scaled grid voltage (v_a) and current (i_a) under magnitude unbalanced three - phase grid voltage.

By observing waveform Fig.7 and Fig.8 it can be concluded that perfectly working under magnitude unbalanced grid voltages, due to which we get near unity power factor and balanced output voltages of matrix converter system.

5.1.6. Performance estimation

By comparing the generated model's metrics to those of other models in terms of total harmonic distortion, execution time, and settling time, its effectiveness was confirmed. The advanced model will be designed in the MATLAB/Simulation. Additionally, the existing methods like you only Look Once Instantaneous Unity Power Factor (IUPF) [29], Positive Sequence (PS) [29], Active Power Oscillation Compensation (APOC) [29], and First Order Sliding Mode-Direct Power Control (FOSM-DPC) [30], High Order Sliding Mode-Direct Power control (HOSM-DPC) [30], Enhanced Exponential Reaching Law-Sliding Mode control (EERL-SMC) [30].

5.1.7. Comparison of the proposed with other present methods in terms of total harmonic distortion

In Fig.9, the recommended MCC-DR's total harmonic distortion is compared to that of the previous study. The proposed scheme Matrix based Deep Reinforcement (MCC-DR) total harmonic rate is 3.10%. While comparing the proposed MCC-DR to other existing methods, the total harmonic distortion level is lower. The harmonic rate for the IUPF method recently in use is 13.22%. While the harmonic level is high when compared to other remaining approaches like PS, APOC.

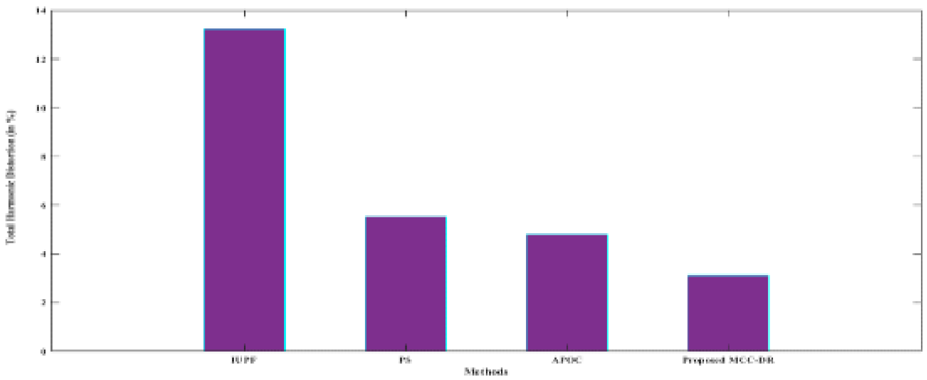


Fig.9. Comparison of the suggested MCC-DR in terms of total harmonic distortion

When compared to other methods such as PS, APOC the PS harmonic level is 5.54 %, which is a great value. APOC harmonic level is 4.80 %, which is poor when compared to all other methods currently in use. when compared to other techniques like PS, APOC. As a result, the proposed MCC-DR performs superior than the other methods already in use.

5.1.8. Evaluation of the proposed with other existing methods in terms of execution time

In Fig.10, the total harmonic distortion of the suggested MCC-DR is compared to that of the previous study. The proposed Matrix based Deep Reinforcement (MCC-DR) execution time is 24.08. While comparing the suggested MCC-DR to other remaining methods, the correctness level is greater. The correctness rate for the EERL-SML method currently in use is 27.4 %. While the execution time is high when compared to other existing methods like FOSM-DP, HOSM-DPC, EERL-SML

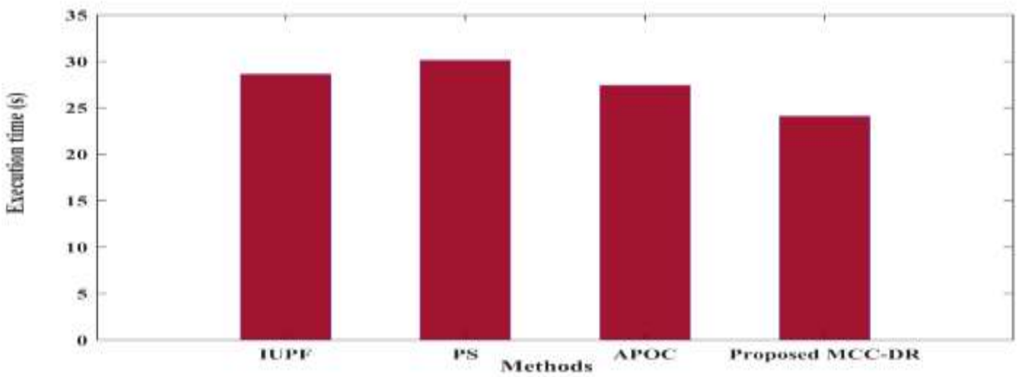


Fig.10. Comparison of the suggested MCC-DR in terms of total harmonic distortion

When compared to other methods such as FOSM-DPC ,HOSM-DPC the HOSM-DPC execution time is 30.1, which is a great value. FOSM-DPC execution time is 28.6 . When compared to other techniques like FOSM-DP, HOSM-DPC, EERL-SML. As an effect, the proposed MCC-DR performs superior than the other methods already in use.

5.1.9. Comparison of the suggested with other existing methods in terms of settling time

In Fig.11, the total harmonic distortion of the proposed MCC-DR is related to that of the previous study. The proposed Matrix based Deep Reinforcement (MCC-DR) settling time is 4.6. While comparing the proposed MCC-DR to other existing methods, the settling time is low. The settling time for the HOSM-DPC method currently in use is 2. While the settling time is high when compared to other standing methods like FOSM-DPC, HOSM-DPC, EERL-SML.

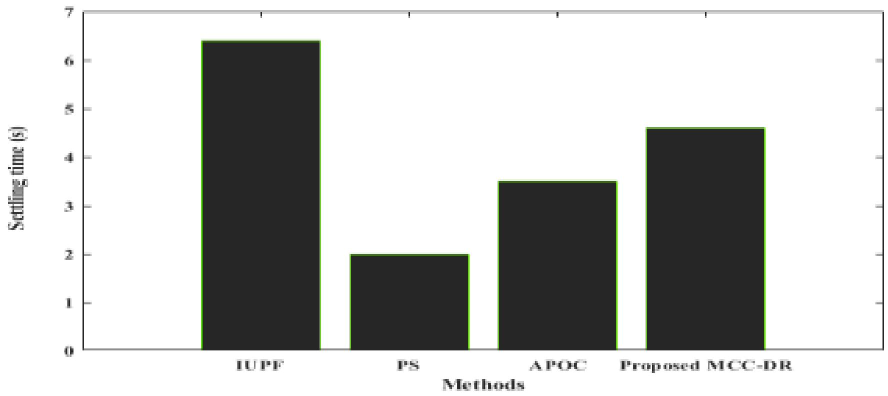


Fig.11. Comparison of the suggested MCC-DR in terms of settling time

When compared to other methods such as FOSM-DPC and EERL-SML the FOSM-DPC settling time is 6.4, which is a great value. EERL-SML settling time is 3.5. When compared to other techniques like FOSM-DPC, HOSM-DPC, EERL-SML. As a effect, the proposed MCC-DR performs superior than the other methods already in use.

Table.2 Comparison of Methods

Techniques	Total Harmonic distortion	Execution time	Settling time
IUPF	13.22%	-	-
PS	5.54%	-	-
APOC	4.80%	-	-
FOSM-DPC	-	28.6	6.4
HOSM-DPC	-	30.1	2
EERL-SML	-	27.4	3.5

5.1.10. Discussion

With the assistance of a contextual investigation, the offered approach's activity is portrayed. A matrix converter system was initially created using the MATLAB system. The matrix converter in the proposed approach improves the Total Harmonic Distortion (THD) and execution time.

Table .3 Performance Analysis

Metrics	Performance
Total Harmonic Distortion	3.10

Execution time	24.08
Settling time	4.6

Table 2 summarizes the performance analysis of the model that has been given. For the MCC-DR dataset, the designed model attained 3.10 total harmonic distortion and 24.08 execution time and settling time 4.6. Moreover, findings are related to voltage approaches in order to confirm the great harmonic in the calculation period of the developed model.

6. Conclusion

All in all, the methodology of a control calculation for a network converter working on uneven framework voltages is a huge development in power hardware. Without the requirement for a DC link, direct power conversion between AC sources of various frequencies and phases is possible when a matrix converter is used. However, running a matrix converter on an unbalanced grid voltage poses major difficulties, especially when it comes to keeping the output voltages and currents in balance. The suggested control algorithm includes several characteristics, such as the use of space vector modulation, a reference frame transformation, and a compensation mechanism, to address these issues. Simulation studies have shown how well the suggested control algorithm keeps the output voltages and currents balanced even when there is a significant voltage imbalance on the grid. This is a significant advancement in the world of power electronics since it opens up a wider range of applications for matrix converters. To study the adequacy of the proposed control calculation under different working situations and to change its boundaries for specific applications, extra evaluation is vital. A detailed analysis of issues like the choice of adequate power devices and the construction of relevant filters and protective circuits will also be necessary for the practical implementation of the algorithm. So there is a requirement to design other classifiers in the future that might overcome these limitations of DL-based models without eliminating any significant behaviour.

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