IoT Communication for Grid-Tie Matrix Converter with Power Factor Control Using the Adaptive Fuzzy Sliding (AFS) Method

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In this work, we propose and encourage the sending of an IoT-based domestic systems conditions small scale programmable framework for grid-tie matrix converter that can efficiently be executed with low-control equipment plan with quick execution capacity. The proposed framework for matrix grid-tie converter has been performed based on an adaptive fuzzy sliding technique and furthermore monitors the grid status through an IoT server. The adaptive fuzzy sliding method was connected to the framework, and a unity power factor was fulfilled alongside the wanted sinusoidal input and output results. The proposed AFS-based matrix converter has been validated through simulation using MATLAB software. The control clock signals are generated for the positive and negative clock pulses of the sequence. Here the sinusoidal reference signal is compared with the switching frequency of the triangular carrier frequency. The hardware results were also verified to validate the simulation. When diverged from other standard techniques, the proposed AFS technique has achieved 97.23% efficiency in full load conditions.

1. Introduction

The Internet of Things (IoT) is a system and a perspective that contemplates the inevitable closeness in nature of an impressive proportion of things/objects. The remote and wired affiliations and exceptional tending to plans can interface with one another and take part with various things or articles to grow new applications/organizations and accomplish shared goals. The essential purpose of the IoT is to be an engaging part to be related whenever, wherever, with anything and anyone, ideally used in any case and any organization. The Internet of Things is another transformation of the Internet. Things make themselves apparent, and they obtain learning by settling on or enabling setting-related decisions because of the way that they can give information about themselves.

Existing projects with connected grid systems that use the grid conversion take into consideration the breeze turbine or power age system. The network converter generator terminal voltage is predicted to be lower the frame voltage list because the matrix bin converter is a down-stage converter. The network converter’s FRT function is tough to grasp. Both observers changed their opinion on the grid converter scarcity ride method. They can get information that has been gathered by various means, or they can be sections of cutting-edge organizations. Shrewd urban communities are requesting conditions where a few zones of advancement meet to enhance socioeconomic improvement and personal satisfaction considerably.

The smart grid (SG) tie matrix converter, the intelligent power grid, could be viewed as the unique instantiation of the
IoT organization in the next future. The whole power grid chain, from the power control plant generation to the power buyers (houses, buildings, mechanical offices, open lighting, electric vehicles, splendid machines, etc.). Counting transmission and dispersion control frameworks will be stacked with information and two-way correspondence abilities to screen and control the power organize wherever, at a brilliant granularity and high precision. For instance, smart houses will be equipped with smart meters and sharp contraptions, while control generators and electric transmission and movement frameworks will be outfitted with various sensors and actuators. The SG join matrix converter hopes to keep an even harmonic between power generation and use by permitting a fine-grained watch and control over the power chain because of the unique number of two-way signals passing on smart objects. The Internet of Things (IoT) will use a more quick-witted lattice to empower more data. Through the IoT, customers, producers, and utility suppliers will reveal better approaches to oversee gadgets, last ration assets, and spare cash by utilizing keen meters, home entryways, brilliant fittings, and associated machines. In this way, the bright lattice grid-tied converter likewise requires the accompanying ability besides the FRT prerequisites.

In the interim, a grid converter has likewise been pulled into numerous considerations as a superior AC-AC converter. The lattice tie network converter is depended upon to achieve higher capability, smaller size, and longer lifetime compared to a standard back-to-back structure. The entire power grid chain is involved houses, buildings, mechanical offices, open lighting, electric vehicles, splendid machines. Counting, transmitting, and dispersing control frameworks will be combined with data and two-way communication capacities to monitor and regulate the power arrangement wherever it is, with incredible granularity and accuracy. Because the identifier of two-way was passed on to smart objects, the SG join matrix converter aims to maintain an equal harmonic between power generation and usage by allowing fine-grained monitoring and control over the power chain. The breeze turbine, or power age system, is taken into account in existing projects with tied grid systems using the grid converter. But since the matrix bin converter is a down-stage converter, the network converter generator terminal voltage is expected to be lower than the frame voltage list. The FRT operation for the network converter is difficult to comprehend.

The grid converter scarcity ride strategy was revised by both observers. It is proposed to reach a standard FRT control protocol with (1) a steady FRT operation, (2) a matrix-reacting current control, and (3) the generator torque control in the middle of the voltage fall in a short period of time. The limitation of IoT devices is that cybercriminals could be accessible to the network and acquire private data. Because we are connected to so many gadgets on the network, there seems to be a possibility that our data may be exploited. They are completely dependent on the Internet and therefore are unable to function properly without it. There are numerous ways for systems to fail due to their complexity. We will lose control of our lives and become completely dependent on automation. However, it is important to comply with this control scheme since the current generator adequacy is simply regulated, and the receptive power (d-axis) is retained at zero. The device converter cannot, however, meet the FRT specifications for structure current at more than 43% voltage drop due to the suppression of the generator current.

This paper proposes an AFS technique for extending the fastening grid converter FRT operation. The current q-axis is constrained by the snubbed mechanism, and the current d-axis is sent to a voltage source inverter of a frame converter on the network circuit. The proposed technology keeps the q-axis current and creates a d-pivot current to expand the engine current. This helps to raise the grid current obtained to prolong the FRT process. This research paper is organized into four sections: Section 1 describes the introduction, the research background is described in Section 2, Section 3 describes the result and discussion, and finally, the conclusion part is described in Section 4.

2. Research Background

Several documents based on open winding topology based on the matrix converters. This topology comprises a total of 18 22 switches (that is, 36 IGBT and diodes) and is organized point by point in the data with the simplest output voltage of 1.5 times the voltage [1]. As the double matrix converter framework is shown, a control unit was suggested for reduced mode voltage in the storage terminals [2, 3]. The V/F approval engine’s open-circle control scheme will display exploratory results. In a modulation method, [4, 5] is expressed in order to decrease the CMV and tests are carried out with a particular resistive load. Moreover, the dual matrix converter conspire has been widely considered for applications in multiphase open-end AC winding drives. For instance, a topology parallel matrix converter [6] 3–5, a total of 60 power gadgets are required, and a switching technique for reducing CMV is being proposed. The structure was experimentally tested with a 5 kW, 5-arrange recorder motor. In the same vein [7], the proposed adjective technique should take the CMV out and expand it to a selection method stack with a double matrix converter configuration of 3–7 (96 IGBTs and diodes required).

The structure consists of an asynchronous PM machine (EM) that is related straight to the internal consumer diesel engine. The active neutral point converter (ANPC) on the EM is connected with a bidirectional DC/DC interlaced multiarrange converter that interfaced with the dc battery [8]. The DC/DC converter is interconnected [6]. The architecture of the electric drive, the control subjects, and the power converter are expressed in this work. The reproduction of a hybrid structure includes a prototype test location consisting of two external magnet-synchronous magnet rotor devices at the same speed and connected to the same shaft [9]. A concept research scale based on proliferation and testing, used as the building square, are two or three difficult voltage restorer converters and the vector transform converter (VeSC) (DVR). They discuss their work aspirations and suggest diminishing exhibits. Effects have been introduced on limited models [10]. The device’s key function is the creation of a wireless sensor network in
various regions and multiple converters [11]. Wireless sensor networks are commonly used in domestic computerization, process monitoring, and wellness management systems. If the controller lacks the network harmonic voltage, the interval transition is constant and thus the FCM is calculated. This can be done if the controller [12] uses a well-designed phase loop (PLL) or if the controller has a short bandwidth. It fulfills this requirement. The leading matrix approach is based on the IoT approach, which allows active multiport network matrices to be expanded. Multi-inverter and multiconverter realization are only feasible for operational amplifiers \((n + m)\), [13].

All the systems mentioned above have a problem with grid-tie matrix converters, so this work proposes a novel AFS method-based grid-tie matrix converter module to solve all the issues. The topology uses two modules for specific and autonomous grouping voltage synthesis [14]. Therefore, the roundabout matrix converter proposed here can make up for adjusted and additionally lopsided voltage hangs/swells. Every module is acknowledged as utilizing a vector-switching matrix converter [15]. The whole topology is vitality storage free, and every module is beat width regulated using straightforward DC duty proportions. This work gives points of interest in the indirect matrix converter modeling, identical circuit, and feedback controller plan.

The general architecture of the proposed converter system is shown in Figure 1. The AC input source has been taken, and it can be associated with a bidirectional rectifier for control of the indirect matrix converter. From that load, the particular parameters are ascertained and put away by utilizing distributed computing [16]. By using closed-loop control, the IoT benefit has been associated with PC and server, so we can see/observe the parameters esteems on the web or by utilizing a cell phone [17]. The Internet of Things gives plans for the coordination of information advancement, which suggests hardware and software computer programs are being utilized to store, recoup, and process data that joins electronic structures used for collaboration between individuals or social events. Since the AFS voltage exchange proportion of the IMC employing the PWM strategy is expanded, it brings about a decrease of THD and enhanced productivity.

2.1. IM Converter Circuit Design. The proposed indirect matrix converter circuit diagram is shown in Figure 2. The LC filter, bidirectional rectifier, and clamp circuits are the main components of this circuit [18]. A clamp circuit compared to film capacitor \(C_c\), third harmonic current injection, fast recovery DC response, and voltage source converter. Three bidirectional switches, an inductor, and bridge legs response are comprised of current third harmonic injection. Under ordinary operation conditions, just a single of the three two-way switches is swung on to infuse the harmonic current into the corresponding input stage. As indicated by the prerequisites of the load, the voltage source converter provides variable frequency, amplitude, and three-phase output results. The clamp circuit is utilized to retain the power put away in the spillage inductance of the load when the framework shuts down.

2.2. IM Working Principles. The working standards of IMC are portrayed as being based on for the switches \(As+\), \(Bs+\), and \(Cs+\) of the rectifier, the change joined to the info stage with the most noteworthy voltage is put away; for the switches \(As−\), \(Bs−\), and \(Cs−\), the change associated with the information stage with the least vitality is continued. The switches \(Ys+\) and \(Ys−\) in the third-symphony current infusion circuit are controlled to frame the third-consonant current by coursing through the inductor \(L_y\).

The bidirectional switch associated with the input organizes with the most diminished preeminent voltage keeps on implanting the third-symphony current. For instance, when the data voltages satisfy \(ua > ub > UC\), switches \(As+\) and \(Cs−\) in the rectifier and the bidirectional switches \(Bys\) and \(Bsy\) in the harmonics current implantation circuit are turned on, as shown in Figure 3, and whatnot. Like this, sinusoidal three-phase input streams and controllable power factors are practical.

2.3. AFS Algorithm Design for Proposed Converter. The AFS system uses neural network architecture to optimize the membership function of the adaptive fuzzy logic controller. Figure 4 illustrates AFS controller with two inputs; error \((e(k))\) and change by mistake \((\Delta e(k))\) is modeled as follows:

\[
e(k) = i_{ref} - i_f, \quad \Delta e(k) = i_{ref} - i_f,
\]

where \(i_{ref} = \) reference current, \(i_f = \) filter output, \(e(k) = \) error, and \(\Delta e(k) = \) error corrected result. The training membership function is obtained using the proposed AFS controller. The inputs are switched into linguistic variables [19]. In this case, five adaptive fuzzy membership functions are defined; NB, NS, Z, PS, and PB. The membership functions utilized for previously, then after the fact, training is shown in Figure 5.

Figure 5 plots the AFS set of the error and change error data which has triangular interests. The proposed AFS picks the change in control concerning voltage to supplant the dedication cycle of the pulse width modulation (PWM) to increase to decrease the voltage until the point that the point when the power is most remarkable, as it appears in Figure 3. AFS has two wellsprings of data, which are: both and the modification in error; and one output managing the pulse width direction to control the DC-to-DC converter. The two AFS input factors, error \(E\) and change of error \(CE\), at inspected times \(k\) described by

\[
Error(k) = \frac{P(k) - P(k - 1)}{V(k) - V(k - 1)}, \quad Change_{Error}(k) = Error(k) - Error(k - 1),
\]

where \(P(k) = \) power of energy generator and \(Error(k) = \) load operation point.
While the moving direction of the point expresses the change of the input error, the AFS consists mainly of three blocks: fuzzification, fuzzy rule, and defuzzification.

Figure 6 represents the AFS set of the Iref output with triangular memberships. The surmising mechanism is assessed from the arrangement of errors by utilizing control rules.

Table 1 demonstrates the desired connection between the input and output factors regards to the membership functions.

2.4. Working Procedure of Adaptive FUZZY Sliding (AFS)

(1) At the start, the introduction of the info factors called the parameters is done, which is in a parallel shape, and the information factors are a fuzzy field.

(2) After information fuzzification, output fuzzification is finished by applying fuzzy administrators like AND or OR administrators.

(3) Membership capacities are characterized and are figured to track the given info/output information.

(4) The parameters related to the enrollment work changes through the learning procedure.

(5) Fuzzy principles are made based on the information yield relationship of the framework.

(6) After making rules, the accumulation of different yields is done, and afterward, the resulting capacities are defuzzified to get an ideal yield.

(7) The gathered output is then prepared by applying it to the neural system through the following propagation strategy.

(8) The error is diminished by performing different emphases in the neural system, and we get a streamlined yield.

(9) The suggested framework for matrix grid-tie converters are based on an adaptive fuzzy sliding approach and also monitors grid status through an IoT

![Figure 1: General architecture of proposed converter system design.](image1)

![Figure 2: Proposed indirect matrix converter topology.](image2)
Figure 3: Equivalent circuit diagram of indirect matrix converter: (a) forward flow control and (b) reverse flow control.

Figure 4: AFS controller.

Figure 5: Membership function of inputs.
server. The framework was coupled to the adaptive fuzzy sliding approach, and a unity power factor was achieved along with the desired sinusoidal input and output outcomes.

2.5. Pseudo Code for IM Converter

2.6. AFS Algorithm for Cloud Server Side. This section discusses how neighborhood information is obtained and the stacking of indirect parameters of the matrix converter in the IoT. In addition, the proposed AFS strategy is given. When the proposed AFS technique is shown to the various centers differently from existing traditional systems such as PID, FUZZY, and ANFIS, the data collection speed and the logical outcome are high. Two and three IoT units represent a parameter, and this benchmark quantifies the IoT contractual qualities of the groups squeezed from the sender near the zone, bunch inaction in the senders near the zone, and the IoT unit differentiation into the goal unit. The probabilities of shift for the relationships can be found for these characteristics. These attributes are objectively presented as follows:

Through linking the electrical power supplied to the IMC and the mechanical energy supplied to the whole device, the IMC dependent on AFS can be tested. The above-listed algorithms have ideal results for an indirect matrix converter unit power factor.

3. Results and Discussion

Simulation is performed using SIMULINK/MATLAB as shown in Figure 4. The SIMULINK library incorporates inbuilt models of numerous electrical and electronic segments and gadgets, for example, diodes, MOSFETs, capacitors, control supplies, etc. The circuit components are associated according to outline without error, the parameters of all parts are designed according to prerequisites, and reproduction is performed.

The above Figure 7 demonstrates the SIMULINK model of an indirect matrix converter utilizing an AFS controller. The hardware points of interest of the proposed framework converter particulars are given in Table 2 and equipment setup is shown in Figure 7.

Figure 8 above shows the current source and the quick reactive power, both with reactive and reactive power. At first, the weighting factor C is set to zero, with the goal of preventing active control. The upper load current THD is 2.37% satisfied by this result, while the lower load current THD is 2.23%. The transitory reactive power minimization is performed, and the actual THD source is 21.73%.

The hardware structure of the proposed matrix converter topology is seen in Figure 9. MOSFETs are used for both optional and low voltage switches. High-voltage side switches are identified by IGBTs. Programmable system-on-chip (PSoC) for the transmission of PWM signals and changes in the final goal for the two-fold platform converter, taking into account the voltage and current recognized. The deliberate forms of the wave show separately.

Figure 10 shows the GUI window, which is the controller module, where the data is changed over to the extraordinary regard using increment factors and a while later shows the characteristics and processed adequacy. In fact, even with the
Input: a source of the indirect matrix converter.
Output: motor.

Begin

Every pattern of power $P_i$ from IMC
$V_{\text{out}} = \text{every pattern generation } (P_i)$.
Source voltage $V_s = \sum_{i=1}^{n} V_{\text{out}} P_i$
End

To select the maximum power
Power ($P$) $= \text{Max} (V_i (V_s))$
Activate the designated MOSFET $M_i$, 
Pattern generation ($PS$) $= \{M_i, [C1, C2, Cn], [V1, V2, V3 \ldots Vn], Vi\}$
Perform pattern generation
$CP = \sum P_i (CP) + P_S$
Stop.

**Algorithm 1**: Pseudo code for IM converter.

Input: indirect matrix converter’s values
Output: load $M$
Input voltage $= V_{\text{in}}$
Begin
Load $9\text{val} \ h1, h20$
If $h2 = \text{null}$
return $h1$
else
return $\text{xmeld} (h1, h2)$;
end
Procedure return $\text{xmeld} (\text{val} h1, h2)$;
IF $h1 = \text{null}$
return $h2$;
If item ($h1$) > item ($h2$)
$H1 \leftrightarrow h2$
$(1\text{child} (h1), rchild (h1)) \leftarrow (\text{xmeld}(rchild(h1), h2), 1\text{child}(h1))$;
return $h1$;
Stop.

**Algorithm 2**: AFS algorithm for cloud server side.

**Figure 7**: Simulation diagram of indirect matrix converter.
issues in data transmission utilizing the WSN in a couple of circumstances, the structure will have the ability to convey supportive watching information, since all getting ready is done over the framework. The going with deficiency examination is used as a piece of the arranged solicitation, like voltage, current, suffering state error, FFT, and THD checking.

Table 2: Design parameters.

| Parameters               | Symbols | Value       |
|--------------------------|---------|-------------|
| Input voltage range      | $V_{in}$| 20 V        |
| Output voltage           | $V_o$   | 440 v AC    |
| Output power             | $P_o$   | 1.29 KW     |
| Magnetizing inductance   | $L_{m}$ | 310 μH      |
| Leakage inductance       | $L_{lk}$| 15.8 μH     |
| Quality factor           |         | 0.61        |
| Resonant frequency       | $F_r$   | 3.84 KHz    |
| Switching frequency      | $F_s$   | 3.84 KHz    |
| Resonant capacitor       | $C_r$   | 1.09 μH     |
| Snubber capacitor        | CT1, CB1| 6.8 nF      |

Figure 8: IM converter voltage and current.

Figure 9: Hardware setup.

Figure 10: GUI snapshot of the cloud server.

Figure 11 shows that the sophisticated and adaptive, fluid sliding control approach has made it powerful to carry out inquiries into various algorithms rather than different techniques.

Figure 12 illustrates a cloud-based safety evaluation using multiple methods, and it shows beyond question that
Figure 11: Performance comparison.

Figure 12: Cloud security comparison.

Figure 13: Comparison of various methods in false ratio.

Table 3: Comparison of features from different algorithms.

| Compared features                  | PI control | Fuzzy   | Dynamic soft switching | AFS  |
|-----------------------------------|------------|---------|------------------------|------|
| Cost                              | High       | High    | Medium                 | Low  |
| Physical structure                | Big        | Big     | Small                  | Small|
| Resistance to work environment    | High       | High    | Medium                 | Low  |
| Finding fault                     | Difficult  | Difficult| Easy                   | Very easy |
| Communication                     | Difficult  | Difficult| Easy                   | Very easy |
| Production planning               | Difficult  | Moderate| Easy                   | Very easy |
| Security                          | Low        | Moderate| Low                    | High  |
| Monitoring data                   | Unavailable| Moderate| Difficult              | Very easy |
AFS has improved its precision compared with other techniques.

Figure 13 shows the correlation of results obtained from the execution of the different techniques for data classification in the IoT server. When contrasted with other regular techniques, the proposed AFS strategy has a lower false classification rate.

The above Table 3 analyzes the correlation features of a different algorithm. When contrasted with other conventional methods, the proposed system gives a perfect result. From the most basic assessment played out, the proposed AFS procedure has been surveyed with various parameters and has conveyed precision when compared with another custom methodology.

4. Conclusion

In this work, we proposed an indirect matrix converter that has the collective focal points of voltage control ability from an indirect matrix converter utilizing adaptive fuzzy sliding methods of IoT, including in nature interleaved operation, wide direction extend, low part focus, little output swell, adaptable pick-up augmentation, and high effectiveness. The proposed topology has decreased the multiple-faceted design that is suitable for large-scale output mix, relative to other customary developments such as the tapped inductor approach, multi-inductor transfer strategy, or transforming strategy. The proposed AFS-based matrix converter has been validated through simulation using MATLAB software. The control clock signals are generated for the positive and negative clock pulses of the sequence. Here the sinusoidal reference signal is compared with the switching frequency of triangular carrier frequency. The hardware results were also verified to validate the simulation. As compared to other conventional methods, the proposed AFS technique has achieved 97.23% efficiency in full load conditions.

Data Availability

The data used in this study will be made available on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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