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A Review on Grid Integration of Renewable Energy Sources using Fuzzy Logic Controller

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***Abstract*:**

This paper presents a comprehensive review of the grid integration of renewable sources using fuzzy logic controller. The Renewable energy sources are connected to grid using a converter. The ability to enhance power quality and grid stability, has gained considerable attention in recent years. This review paper evaluates the advancements, applications, advantages, and limitations of in renewable energy-based grid integration. Furthermore, it discusses about the performance evaluation methodologies associated withcontroller used. Finally, future research directions and challenges in this field are identified to guide researchers and practitioners in developing more effective and reliable solutions for renewable energy grid integration.

Key words: Grid Integration, Renewable energy, Fuzzy logic Controller

Introduction:

Since the grid integration has many challenges the irregular nature of the prevailing RER, e.g., sun powered photovoltaic (PV) and wind frameworks, postures operational and specialized challenges in their successful integration by hampering organize unwavering quality and soundness. This article audits and examines the challenges detailed due to the lattice integration of solar PV frameworks

and proposed solutions [1]. This consider gives potential move scenarios to full supportability for Turkmenistan in power, warm and transport segments. Endless sunny forsake fields of Turkmenistan may empower the nation to switch to 100% renewable vitality by 2050, with prospects to have 76% solar photovoltaics and 8.5% wind power capacities in a Best Arrangement Situation. Seven distinctive move scenarios, with distinctive GHG emanations taken move rates, have been examined to illustrate distinctive conceivable ways towards full supportability in a cost-efficient way. The comes about of the think about illustrate that a 100% renewable vitality framework, in any case of the move rate, will be lower in fetched than a nonstop dependence on fossil fuel [2].

within the early days of selection of RE integration with the grid was not an issue and RE may well be associated or detached from the integration. But with the increment in RE infiltration network integration is an issue because it would influence grid integration. The integration of renewables has positive as well as negative impacts on it. The positive impacts incorporate reliable power, energy security, decrease in contamination and global warming. In any case, the issues emerging from integration to grid are exceptionally much challenging and require consideration [3]

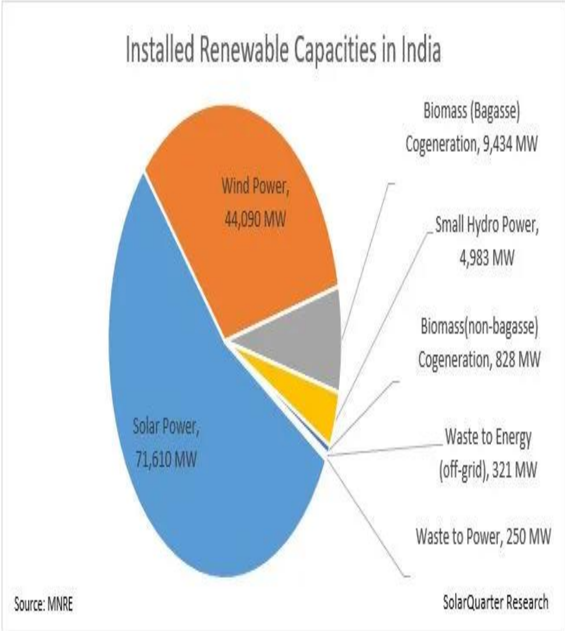

Figure.1: Renewable Energy Capacities in India [4].

The paper shows the issues which arise as the cause of integration of integration with existing power grids.it gives the issue and the solution for the issues, in order to give the energy from renewable sources [5]. The paper presents the issues and challenges during the grid integration of renewable energy sources with possible solutions and to minimize the problems in grid integration energy storage and use of dump load and MPPT technique could be used for reducing the problems in the renewable systems. This paper [6] gives the smart grid integration of renewable energy sources which gives a different model and control system which presents renewable energy sources in to smart grid and it is measurable to know how many sources could be added to the design requirements, all the integrating methods and technologies are given in this.

The paper gives the control system for communication to grid operator and able to either operate in MPPT (Maximum power point tracking) or LPPT (limited power point tracking). The MPPT and LPPT control is implemented through a fuzzy logic controller and the result can be seen in reference [7]. The paper gives the steady state performance of grid connected to a PV system, the system is created in Simulink through daily weather conditions and tested its performance and made to be satisfied it with high power quality. the power factor of the inverter is improved with synchronous frame utility grid codes based control system [8].

The paper gives the design and implementation of solar hybrid grid system, the technique and the methods are explained in the paper and it is willing to give the dependency reduction over grid, the end of this says about the sources cost and installation of it and also proposes to use new renewable sources [9].The brief information about the power quality issues that are caused due to grid integration are shown and to clear it the algorithm which is used is explained in the further study of it,The prototype is developed based on the design of it,the proposed system performance and results are obtained in dynamic and steady state conditions and they can been seen in ref [10].The power quality issues which arises in the topology which include grid connected renewable energy system, which is the combination of wind turbine which is driving the synchronous generator and PV array with control strategies to improve. The grid availability and the vulnerability of power generation is reduced used the different control technique [11]. The grid in this paper is connected to improve the power quality of the system. The negative impact of the grid integration is slightly explained to know the consequences of it, the renewable energy sources integration int o smart grid and PQ conditions represents the two standards of distribution system operator, all the issues and the solutions for power quality problems are shown [12].

Challenges with grid integration:

The integration of renewable energy into power grids have a set of challenges that need to be addressed to get the stability, reliability, and efficiency of the system. The clean and environmental friendly power generation sources will give the green house emission reduction by reducing the use of fossil fuels as per the requirement [1].

The challenges that are caused in grid integration are as follows:

Output power prediction:

The operation of the grid is having the uncertainties that have on the demand side of electrical grids. In the case of wind turbines predictions plays an important role in reducing the cost of production. The wind turbines as they are the sources of electricity they became useful for the management of power. The approaches that are based on the historical data which may be wind generated power which results in future power generation [13].

Future power generation will be estimated using statistical and intelligence methods based on previous data, including generated electricity and wind. The mathematical prerequisite for the time series-based statistical method is represented by the concepts of probability, statistics, and stochastic processes. The regression technique and its numerous subsets [14], [15], Kalman filter [16], and copula theory [17] are a few examples of the models that are utilized. The creation of clever arrangements, like the prediction's usage of artificial intelligence, has been spurred by innovative improvement. An intelligent approach's forecasting results demonstrated a high level of accuracy and consistency in addition to its ability to handle nonlinear time series [18] because of their adaptable and flexible nature [19].

Using a variety of techniques, such as the Weibull probability density function [20] [21], Rayleigh PDF [22], Monte Carlo method [23], time series analysis [24], statistical method [25], the researchers models the stochastic behaviour of the wind speed. Subsequently, they computed the wind farms' power production using the power curves associated with wind speed. Manufacturers give power curves, which are mathematical functions that accurately connect wind speed to output powers [26]. When Jordehi [27] examined potential methods for addressing power system uncertainties, he discovered that scenario-based analysis (SBA) and Monte Carlo simulation (MCS) are more straightforward and straightforward to use than point estimate and probabilistic approaches. But the methods of MCS and SBA are computational expenses. A two-stage methodology was created by Liu et al. to estimate the forecast durations across several endeavours. Initially, the Elman, generalized regression, and extreme learning machine neural networks were the three artificial neural networks (ANN) that the genetic algorithm (GA) integrated to create a weight-varying prediction model. Using a nonparametric kernel density estimate, the prediction intervals were ascertained in the second stage. The trial findings on a 15kW grid-connected photovoltaic system showed that it was better to the standard short-term prediction techniques. To create another prediction model, Elman neural networks, K means, and Gray relational analysis were used [28].

The beta probability density function (PDF) was utilized to simulate the stochastic behaviour of solar irradiation [29]– [30], as well as Weibull PDF [31]. Subsequently, the PV plants' output power from solar radiation was computed.

Impact of Frequency:

Because PV systems are intermittent, integrating them into the grids raises the possibility of a generation and demand mismatch. This load requirement as well as a mismatch in generation can result in frequency fluctuations in the networks, which can cause a partial or complete loss of electricity supply. The effect of a higher PV share, which accelerated the rate of change of frequency (ROCOF) and may cause the system to collapse during natural overloads, was examined by Rahouma et al. The authors of [94] created an algorithm to calculate the right amount of generation reserve for a PV plant by using the features of the frequency behaviour to prevent significant harm or blackouts. [32]. Two transmission networks used as IEEE benchmarks were examined by Qaid et al. [33]. It was demonstrated that when solar PV output reaches a penetration rate of more than 40%, the systems will collapse in the worst-case scenario because of the loss of inertia. The frequency impact of PV power plant outputs.

The addition of wind energy to the electrical grid helps to lessen the inertia of the system as a whole, which has a significant impact on smaller, isolated systems [[34], [35]]. The majority of wind power plants' control systems disconnect the mechanical system from the electrical system in the event of any disruption that lowers wind power plants, which adds to the inertia of the network. [36]. By utilizing the wind turbine mass during a disturbance, the installation of an auxiliary controller to the wind turbine central control unit, according to Morrenetal [37], may alter the torque set point to make it flexible to the fluctuation of grid frequency. Conroy and Watson [38] suggested a controller that uses the same idea to regulate a permanent magnet synchronous generator's (PMSG) output power depending on grid frequency. On a PMSG wind turbine, a different control method was evaluated during frequency oscillations in [39].

Impact of Harmonics/ Power Quality Issues:

Harmonics are created by the power electronic converters used to integrate PV into the grids, and they might impair network-connected devices and lower its longevity and efficiency. Research was done on the harmonic properties that arise from the integration of many photovoltaic systems into the grid [[40], [41], [42] [43]. Harmonics were discovered when Sreedevi et al. [44] investigated the impact of integrating the PV system in the Indian electrical grid. High-frequency harmonics from PV inverters placed in a Brazilian solar farm, where the current distortion reached up to 2% of the fundamental frequency, were measured by Torquato et al.[45]. Ref.[46] conducted an experimental investigation of the harmonics produced by PV power plant integration to the grid and created a model to address the harmonics.

Low harmonic emissions are one of the requirements for wind turbines to provide energy of an acceptable power quality, much like other conventional generators [47].The incorporation the grid's wind turbines will introduce harmonics at various network levels. In order to assess harmonics and create mitigation strategies, we must identify the factors that lead to their release. The wind turbine system's harmonic-producing components are the collector bus cables, turbine transformers, filters, capacitators, power factor correction devices, and power electronic converters. [48] [49]. The types 1, 2, 3, and 4 wind turbine harmonic models are covered in [50] [51]. A number of techniques for figuring out harmonics are covered in [52], including the IEC current and voltage phasor approach, the distorted and non-distorted current method, the superposition method, the harmonic power flow method, and the harmonic state estimate method.

In order to lessen the current harmonics that each wind turbine produces, Reis et al. [53] have developed a control method that integrates the roles of filters into full-converter wind turbines. By controlling the inverter voltage's angle and amplitude, the established technique reduced current harmonics and eliminated harmonics that weren't the same as the bus bar inverter voltage. They discussed how the suggested approach got rid of harmonics without requiring hardware modification. In order to investigate the frequencies of harmonics of mechanical and electrical transient states of wind turbine variables, Vargas and Ramirez [54] suggested an expanded harmonic domain model.

Transmission, Communication and Security Challenges:

The aforementioned difficulties might cause the PV production to malfunction and unintentionally reduce. To address the problem of congestion, Sreejith et al. In light of RER integration, [55] described many series of compensated FACTS devices to improve the transmission lines' capacity for power transfer. The inventors of [56] increased the network's capacity for power transfer by converting the PV inverter into a STATCOM. Additionally, the authors used PV-STATCOM to improve power system stability in emergency situations. Zedak et al. [57]proposed employing the internet of things (IoT) to store temperature, voltage, current, and other pertinent data from the solar field in order to address the communication difficulties. This would enable event forecasting, preventive maintenance, and system monitoring and fault diagnosis. Data coordination between RER plants and system operators is affected by cyberattacks on power outages, as demonstrated by Ref. [58]. The cyberattack on the electric grid including PV units with reactive power capability was examined by Teymouri et al. [59]. This cyberattack put the stability of the system at risk and caused the network integrated RER to become unstable. A sliding mode-based observer was developed in response to security concerns in order to identify and quantify assaults in which extracted data was used to make up for damaged data [60]. In conclusion, Qi et al. [61] put forth a comprehensive architecture that is resistant to assaults in order to shield the grid-integrated RER infrastructure and the grid as a whole from malevolent cyberattacks while maintaining grid stability, resilience, and dependability. However, power system researchers should look into and develop more approaches for the safe and secure functioning of future grids, given the significance and criticality of the transmission, communication, and security concerns.

Wind power facilities are typically located distant from conventional load centers, which puts strain on the transmission infrastructure and weakens the power access point to the grid [62], [63]. The National Renewable Energy Laboratory (NREL) suggested a wind curtailment reduction method by continuing to expand transmission infrastructure in response to the remarks that were previously mentioned [64]. To effectively incorporate wind energy into the mix of energy sources without curtailment, more study on strengthening transmission infrastructure is required.

Socio economic and environmental challenges:

When compared to the environmental effect of traditional energy sources, the impact of wind energy is negligible [65]. Wind energy produces no greenhouse emissions and requires no fuel, in contrast to coal and oil. In a matter of months, the clean energy produced by the turbine will equal the energy used to make and transport the materials needed to build the wind power plant [65]. It is believed that onshore wind turbines alter the landscape. A concrete jungle may result from their turbine, route, transmission, and substation network [66].

PV systems are a clean energy source, and the sector boosts the economy overall and has produced millions of employment over the years. However, it has detrimental effects on the ecosystem. In order to manufacture the solar cells, it needs big project areas, a significant volume of treated water throughout the production process, and standard cleaning procedures involving hazardous compounds [67]. When used properly, these dangerous components of PV modules don't endanger the environment or public health. However, malfunctioning or abandoned units might put the ecosystem in a dire scenario [68].

According to Padmanathan et al. [69], institutions and organizations may play a crucial role through awareness initiatives in changing the perceptions of the various citizen groups in India regarding the usage and significance of the RER. Additionally, attractive regulations like net metering, incentive initiatives, feed-in-tariffs, and installation services promote the adoption of PV in rural regions [70]. The authors of [71] discussed how Irish higher education institutions may promote the growth of sustainable energy by creating a novel approach that combined social and quantitative analysis to adopt PV systems.

Fuzzy Logic Controller:

A fuzzy set is characterized without fresh boundaries Current inquire about on the FLC usage in the application of a DC to AC converter (inverter) to change over the PV control for AC loads has gotten impressive attention [72].

A fuzzy set A in the universal set U is a set of ordered pairs of a generic element u and its membership degree

$\mu A(u)$ as $A = \{ (u, \mu A(u)) / u \in U\}$ [73].

The first step during the FLC design was the creation of a knowledge base, i.e., fuzzy rules, expressed in terms of statements, conditions, and actions. Starting from the condition "TRUE" (i.e., the situation is verified), a set of rules was defined for the errors. Then, conditions were defined accordingly, obtaining variable reactions. The number and type of membership functions (MFs) represent a key point for the controller, being a tradeoff among achievable performance, memory space occupation, and execution speed. Their shape depends on the input data distribution and can influence both the tracking accuracy and the execution time [74], [75].

Architecture of Fuzzy Logic Controller:

The basic FLC architecture with three main components: (i) fuzzifier unit, (ii) knowledge-based rules and inference engine, and (iii) defuzzifier unit. The other blocks are the input and the output and references of the system which are to be controlled. The architecture of fuzzy logic controller is shown in figure below:

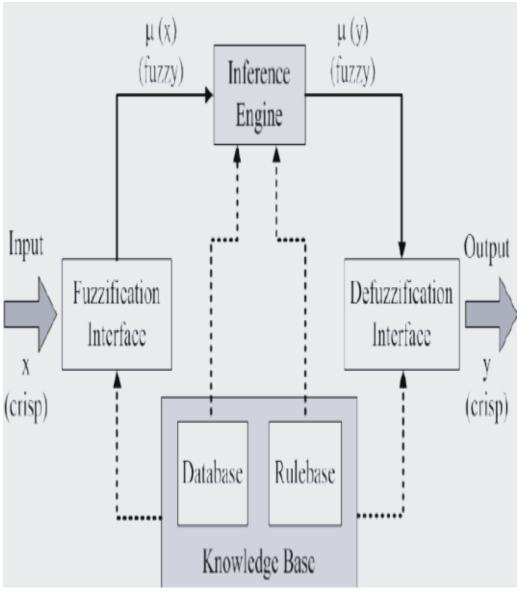

Fig: Basic Type-1 FLC Architecture

The output of the fuzzy system is obtained with the defined fuzzy rules and fuzzy sets. The fuzzy expert system lumps all fuzzy output sets into a single fuzzy set and produces a single crisp solution for the output variable [76].

A. FUZZIFICATION

The input data can be processed by the fuzzy system, the degree to which the crisp values of each input belong in the appropriate fuzzy sets are to be determined [76]. They are transformed into a degree of membership by the Membership Function [77].

B. DEFUZZIFICATION

The final step in the inference process is to extracts the crisp output value from a fuzzy output set [78]. The process takes output fuzzy set and produces a single-number output. The centroid technique is the popular method of defuzzification. This method identifies a point which gives the centre-of-gravity of the fuzzy set at a certain interval [76].

C. FUZZY INTERFERENCE

IF–THEN rule logic gives the fuzzy output set in which it maps the input to an output by utilizing the theory of fuzzy sets. Compared to Sugeno style Mamdani method is most popular method used to interference process [78]. The fuzzy system lumps all fuzzy output sets into a fuzzy set and generates crisp results for the output variable [76].

D. Tpye-2 Fuzzy Logic System

The Basic fuzzy system is also known as type-1 fuzzy logic system (T1FLS) might have good controlling ability in various applications, where it lags to define the uncertainties of the systems' noises, nonlinearities and environmental variations. Type-2 fuzzy logic system (T2FLS) defines the system's uncertainty through a bounded region in membership function (MF) as upper and lower MFs as shown in figure below [79].

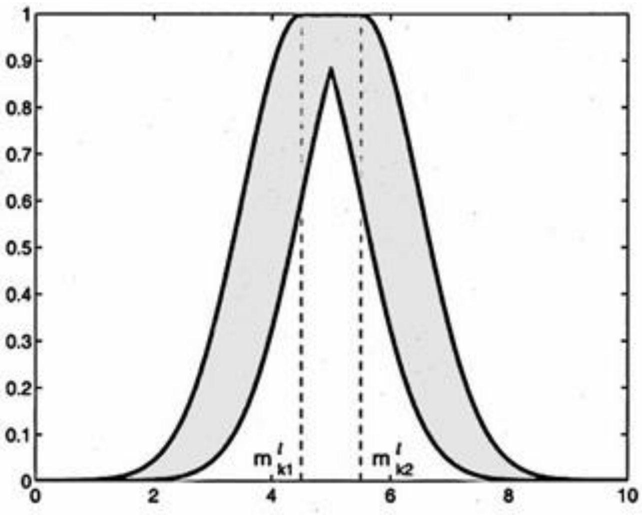

Fig: Type-2 membership function with the shaded region.

In T2FLS, the structure of rules are same as T1FLS except that they involve in type-2, he inference process requires additionally to obtain unions and intersections of type-2 sets, and compositions of type-2 relations, the output process is involved a type-reduction process as similar process to type-1 defuzzification to generate type-1 sets from type-2 sets and then defuzzified to crisp output [80].

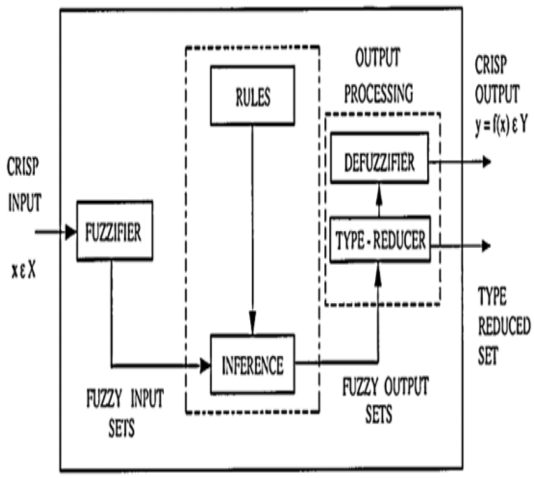

Fig: Overview of type-2 Fuzzy logic system

Rule Based Fuzzy Controller:

The selections of system variables, MFs, and fuzzy rules development are necessary to develop the FLC-based control algorithm for a system. In an electrical system, inputs to the FLC system are the parameters (electrical signals) originating from the “process to be controlled”. However, the FLC output is the control process of the input parameters.

The FLC structure is a double-input-single-output type. For the proper and accurate fuzzy system operation, the input and output variables of the universe of discourse should be normalized to fit into the interval value of -1 and +1. Each input variable obtains five triangular-type MFs and two trapezoidal-type MFs.

In the fuzzy logic-based inverter control system, an error in the discrete time, and its rate of change, de/dt, are selected as input variables for the FLC. The controller output, u(k), is selected as the FLC output variable [77].

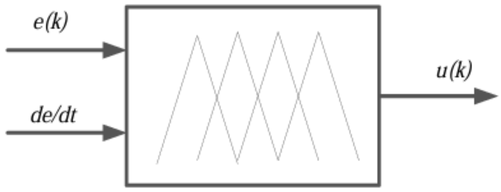

Fig: Input and output variables of FLC

Conclusion:

This article reviewed and discussed about the challenges and solutions of using solar and wind energy in integration with the grid using one of the MPPT Technique Fuzzy logic technique. The clear view of challenges in grid integration are explained. The technique used for the integration is discussed and the benefits of the technique is shown. The usage of wind and solar energy are very increasing in the market and it is cost efficient. The brief view on fuzzy logic controller and the types of fuzzy logic controller are discussed. The membership functions of the fuzzy sets and the rule based fuzzy technique The solutions for the problems regarding grid integration and some solution shave been found out. In this article it is discussed about most of the challenges and the solutions of the grid integration problems. This study gives the overview of the grid integration of solar wind energy using the fuzzy logic technique and the use of renewable sources for the development of the future.

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