

Smart Grid based Wireless Communication in 5G Network for Monitoring and Control Systems in Renewable Energy Management

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Abstract:

Wireless networks are becoming ubiquitous and as the cost of equipment decreases and performance increases, it becomes both economically and technologically feasible to deploy wireless networks in power systems and industrial environments for a wide range of applications. They have advantage of providing diverse controlling features through a unified communication platform. Application of such networks in the smart grid/industrial environments is under active research and expected to become an integral part of the power system. This research propose novel technique smart grid communication in wireless 5G networks for monitoring and controlling management. Here the smart grid designing has been done based on wireless communication networks. The smart grid network for renewable energy has been controlled using Stackelberg equilibrium based SCADA (supervisory control and data acquisition) method. The control method based collected data has been monitored for detection of malicious activities in the network using supervised radial basis fuzzy systems. The experimental analysis has been carried out based on control system and network malicious activities. Here the control system based parameters analysed are Scalability of 65%, QoS of 71%, Power consumption of 41%, Network Efficiency of 92%. Then machine learning based malicious activities detection in terms of accuracy of 96%, network security of 88%, throughput of 94%, Network delay of 41%. Proposed method supports interoperability of multiple types of inverters, is scalable and flexible, and transmits data over a secure communication channel.

Keywords: Smart grid, wireless 5G networks, wireless communication, monitoring, controlling management

1. Introduction:

According to one definition, a smart grid (SG) is an integrated device that uses a two-way flow of electricity as well as data to increase the efficiency, dependability, and flexibility of the energy network. The two most crucial goals are to solve the height issue by enabling real-time communication between user as well as application and to enhance the resilience of electrical network by integrating renewable energy sources. The peak load strain may reduce as customers select to modify their energy usage in response to price or environmental concerns. As a result, Smart Grid may accommodate increased customer demand without constructing opulent infrastructure. Additionally, integrating renewable energy sources would enhance energy diversity as well as lessen our reliance on fossil fuels except the greenhouse gases. Real-time two-way communication as well as tool control, as stated by DOE, form the core of the smart grid. It is highly preferred to monitor as well as control home devices over wi-fi networks given consumer mobility as well as independence. This is similar to the

concept of "Smart Home" [2], in which all of home's appliances are connected to cutting-edge mobile devices. A real-time, comfortable wireless communication interface between user as well as monitored/controlled devices is fundamental structure in this case. Several organisations, including NIST, IEEE, ETP and IEC, EPRI, for example. Those organisations are also rigorously researching a diverse set of requirements and the harmonisation of various standards [4]. It can be described in a variety of ways depending on its useful, scientific, or helpful features. According to description provided by the United States Department of Energy, "a smart grid uses digital era to enhance reliability, security, and performance (both economic and power) of the electrical device from large era, via the delivery structures to strength clients and a growing range of dispensedera and storage assets" [5]. SG is the integration of electrical, data, and communication method to make power grid more dependable, flexible, green, and strong. It is a smart PG that incorporates a variety of alternative and renewable energy sources. The most notable

smart grid deployment capabilities are automated monitoring, information acquisition, management, and emerging conversation technology. The use of a diverse set of communication standards necessitates evaluation as well as optimization based on constraints and needs [6-9]. These needs are determined by location of coverage, the type of utility, the bandwidth required, and many other factors [10]. According to the programmes of communication technology at various levels of smart grid deployment, SG hierarchical conversation networks are classified as HAN, NAN and WAN. Modern concept is a variable fee profile provided to the customer the day prior to delivery by a retailer. After transmitting to the client, this overview is considered fixed, and the customer can rely on it. The actual rate account will look different each day, reflecting market conditions that change on a daily basis. These variations may also increase with increasing generation from fluctuating resources such as wind power and photovoltaic mobile. In general, this concept allows for the integration of loads as well as generation units at the client site, as it is entirely up to the customer which devices are permitted to be managed in accordance with the variable tariff. To permit in-domestic energy control, a appropriate domestic system is required together with an vehicle home management device coupled to a smart meter.

2. Background study:

SG [1] is taken as a present day electric PG method for greater efficiency as well as consistency through automated control, excessive electricity converters, current communications infrastructure, sensing and metering technology, and present day energy management strategies primarily based at optimization of call for, electricity and community availability, and so forth. While modern-day energy methods are based totally on a strong facts and verbal exchange infrastructure [2]. Application of wireless technologies within the smart domestic is dealt with via declaring benefits and boundaries of to be had tactics for the answer of heterogeneous and coexisting issues related to the distributed monitoring of the home and the inhabitants. Some warm demanding situations going through the exploitation of non-invasive wi-fi gadgets for user behaviour tracking are then addressed and the software fields of smart strength control and elderly human beings monitoring are selected as representative cases where the estimation of user sports improves the ability of region-aware offerings in the smart domestic. This paper proposes a virtual machine for circumstance tracking [3]. Kantarci et al. [8] evaluated the value powerful strategy for residential load control in smart

machine through the usage of wireless sensing networks (WSNs). The evaluation changed into made on basis of value of power, reliance on customers' most demand, power saving and reduction in CO₂ emissions, through applying in-domestic-electricity management (iHOM) method and became as compared to optimization based residential electricity control (OREM) method. Uyar and İlhan suggest a GA based totally trained RFNN for detection of coronary heart illnesses [12]. Fei and Wang suggested an AFNN manipulate scheme based on a RNN community to beautify performance of a shunt active energy filter [13]. Camastra et al. suggested a fuzzy decision method for environmental hazard exams of hereditarily changed flowers, depends on a Mamdani inference [14]. Liu et al. suggested a widespread prediction device known as a recurrent self evolving FNN (RSEFNN), which applied online gradient descent mastering guidelines to categorize using fatigue in EEG regression issues [15]. Nazari et al. suggested a fuzzy inference, fuzzy analytic, and hierarchy system-primarily based clinical selection help gadget for detection of heart ailment. Agreeing fuzzy inference policies have been obtained the usage of professional expertise [16]. Ilbahar et al. suggested method to danger valuation for occupational health, based totally on Pythagorean fuzzy analytic hierarchy manner as well as fuzzy inference method [17]. Mohamad and Mukhtar suggested a weighted Mamdani type fuzzy inference version for a comparative best desire machine, based totally on fuzzy if-then policies [18]. Electricity is a essential usefulness for functioning of society as well as for services supplied by ICTs. Many conceptions of SG, including dynamic pricing, distributed technology, and demand managing, have extensively squeezed operation of ICT services, specially, conversation networks as well as information centers [4] S.Ramkrishan (2013) explores a technique to facilitate management of electrical strength within context of evolving SG ideas which are constant with sustainability practices. Method displays a cyber-bodily software program machine that includes net-enabled bodily devices as well as REST full APIs to permit tracking and controlling electric appliance household [5].

3. Methods and materials:

This section discuss novel technique in smart grid communication in wireless 5G networks for monitoring and controlling management. Here the smart grid designing has been done based on wireless communication networks. The smart grid network for renewable energy has been controlled using Stackelberg equilibrium based SCADA (supervisory control and data acquisition) method. The control system

based collected data has been monitored for detection of malicious activities in the network using supervised radial

basis fuzzy systems. The proposed controlling and monitoring system is shown by figure-1

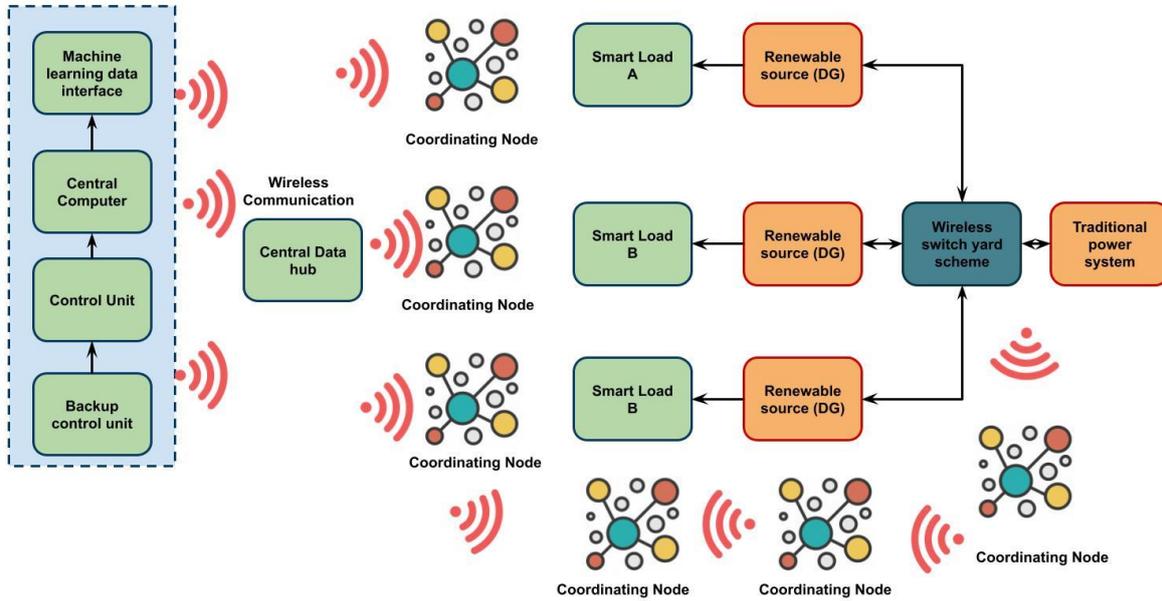


Figure-1 Proposed controlling and monitoring system

Physical Layer:

Consider all wi-fi nodes in suggested method use IEEE 802.11a bodily layer. IEEE 802.11a [11] is a WiFi widespread that gives 12 nonoverlapping channels inside unlicensed countrywide information infrastructure radio band over 5-GHz band [11]. Every channel in IEEE 802.11a helps as much as five-Mb/s records charge with a high bandwidth of 18 MHz. In america, middle frequencies of channels inside lower as well as center frequency tiers of U-NII band are similarly spaced via 20 MHz beginning from Channel 36. Every wireless node connects to a concentrator both at once, if transmission variety lets in, or via a multihop hyperlink.

Assume a physical conversation channel with path loss has a dual-slope method [12], which is represented by means of eqn (1)

$$PL = \begin{cases} 20\log_{10} \frac{4\pi f}{c} + 20\log_{10} d & d \leq d_B \\ 20\log_{10} \frac{4\pi f}{c} + 20\log_{10} d_B + \gamma \cdot 10\log_{10} \frac{d}{d_B} & d \geq d_B \end{cases} \quad (1)$$

wherein f is running frequency, c is velocity of mild in unfastened area, γ is course loss exponent, and dB is breaking-point distance. Orthogonal frequency division multiplexing method with the intention to aid more than one

records quotes with one of a kind modulation methods. Primary rate is used for transmitting bodily-layer convergence technique (header with a BPSK modulation method. Highest statistics transmission fee (54 Mb/s) and different lower charges are maintained through M-QAM as a modulation scheme. In truth, PER for a tough-choice Viterbi decoder is bounded from eqn (2)

$$PER_{mod} \leq 1 - (1 - P_{hd_{mod}})^S \quad (2)$$

wherein S is dimensions of packets in bits, and Phdmod is union certain of primary-occasion mistakes probability represented through by eqn (3)

$$P_{hd_{mod}} \leq \sum_{d=d_{free}}^{\infty} a_d P_{d_{mod}} \quad (3)$$

wherein dfree is minimum unfastened distance of convolutional code, ad is overall range of errors events of weight d, and Pmod may be received as by eqn (4)

$$P_{d_{mod}} = \begin{cases} \sum_{k=(d+1)/2}^d \binom{d}{k} p_{mod}^k (1 - p_{mod})^{d-k} & \forall \text{ odd } d \\ \frac{1}{2} \binom{d}{d/2} p_{mod}^{d/2} (1 - p_{mod})^{d/2} + \sum_{k=d/2}^d \binom{d}{k} p_{mod}^k (1 - p_{mod})^{d-k} & \forall \text{ even } d \end{cases} \quad (4)$$

where the modulation scheme mod \in {BP SK, QP SK, M-QAM}.

Control management using Stackelberg equilibrium based SCADA:

We observe the specialty of Nash equilibrium at UC-level as well as Stackelberg equilibrium for all degree recreation. Note that user-facet software function is convex as well as restrictions are linear. We begin with aid of enjoyable the minimum energy constraint (three) after which locate the important price range that makes high demands viable. For every person $n \in \mathcal{N}$, combined Lagrange function is represented as follows by eqn (5):

$$L_{user,n} = \gamma_n \sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} \ln(\zeta_n + d_{n,k}(t)) - \lambda_{n,1} (\sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} p_k(t) d_{n,k}(t) - B_n) + \sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} \lambda_{n,2}(k,t) d_{n,k}(t) \quad (5)$$

where $\lambda_{n,i}$'s are Lagrange multipliers. By Krush-Kuhn-Tucker important conditions by eqn (6)

$$\begin{aligned} \frac{\partial L_{user,n}}{\partial d_{n,k}(t)} &= 0, \forall t \in \mathcal{T}, \forall k \in \mathcal{K} \\ \lambda_{n,1} (\sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} p_k(t) d_{n,k}(t) - B_n) &= 0 \\ \lambda_{n,2}(k,t) d_{n,k}(t) &= 0, \forall t \in \mathcal{T}, \forall k \in \mathcal{K} \end{aligned} \quad (6)$$

$$\lambda_{n,1}, \lambda_{n,2}(k,t) \geq 0, \forall t \in \mathcal{T}, \forall k \in \mathcal{K}$$

$Dn,k(t) > \text{zero}$, okay $\in \mathcal{K}$, $t \in \mathcal{T}$: In this example, because $\lambda_{n,1} > \text{zero}$ and $\lambda_{n,2}(ok,t) = \text{zero}$ for all $t \in \mathcal{T}$ and $ok \in \mathcal{K}$, thresholds by eqn (7)

$$\begin{aligned} \frac{\partial L_{user,n}}{\partial d_{n,k}(t)} &= \frac{\gamma_n}{\zeta_n + d_{n,k}(t)} - \lambda_{n,1} p_k(t) = 0, \forall t \in \mathcal{T}, k \in \mathcal{K} \\ d_{n,k}(t) &= \frac{B_n + \sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} p_k(t) \zeta_n}{KT p_k(t)} - \zeta_n, \forall t \in \mathcal{T}, k \in \mathcal{K} \end{aligned} \quad (7)$$

Consider eqn (7) also holds for $d_{n,k}(t) \geq 0, k \in \mathcal{K}, t \in \mathcal{T}$. Similar analysis as in past case by eqn (8),

$$d_{n,e}(f) = \frac{B_n + \sum_{c \in \mathcal{K}} \sum_{f \in \mathcal{T}} p_e(f) \zeta_n}{(KT-1)p_e(f)} - \zeta_n \quad (8)$$

Note that since $dn,1(1) = 0$, thresholds by eqn (9)

$$B_n = \zeta_n (KT p_1(1) - \sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} p_k(t))$$

$$d_{n,c}(f) = \frac{B_n + \sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} p_k(t) \zeta_n}{KT p_c(f)} - \zeta_n \quad (9)$$

By finances constraint (i.E., $\sum_{k \in \mathcal{K}} \sum_{t \in \mathcal{T}} p_k(t) d_{n,k}(t) \leq B_n$) we will see that when $dn,k(t) = 0$ for all $k \in \mathcal{K}$ and $t \in \mathcal{T}$, user n has a zero price range. Introduced fees cannot be endless due to nature of Stackelberg equilibrium. Denote method space of person $n \in \mathcal{N}$ by \mathcal{F}_n and method space of all users with the aid of $\mathcal{F} = \mathcal{F}_1 \times \dots \times \mathcal{F}_N$. Denote the approach area of UC $k \in \mathcal{K}$ at $t \in \mathcal{T}$ by $\mathcal{L}_{k,t} := [p_k^{\min}(t), p_k^{\max}(t)]$ Note that $p_k(t) \in \mathcal{L}_-(ok,t)$ for all $t \in \mathcal{T}$ and $k \in \mathcal{K}$. Method area of UC okay for complete time horizon is $L = \mathcal{L}_1 \times \dots \times \mathcal{L}_K$ and method space of all corporations is $L = \mathcal{L}_1 \times \dots \times \mathcal{L}_K$ Earlier stating our fundamental method, require subsequent game-theoretic ideas from [7]. Vector of charges $\mathbf{p}^* \in L$ establishes a Nash equilibrium for fee choice sport on UCs-degree if by eqn (10)

$$U_{gen,k}(p_k^*, \mathbf{p}_{-k}^*) \geq U_{gen,k}(p_k, \mathbf{p}_{-k}^*), \forall p_k \in \mathcal{L}_k(p_1, \dots, p_K) \in \mathcal{L}_K$$

$\mathbf{d}^*(\mathbf{p}) = \{d_1^*(\mathbf{p}), d_2^*(\mathbf{p}), \dots, d_N^*(\mathbf{p})\}$ (10) in which for every $n \in \mathcal{N}$, $d_n^*(\mathbf{p})$ is specific maximizer for $U_{user,n}(d_n, \mathbf{p})$ over $d_n \in \mathcal{F}_n$. For sport taken into consideration right here, Stackelberg equilibrium is described as $(\mathbf{d}^*(\mathbf{p}), \mathbf{p}^*)$

Figure-2 shows a excessive-degree evaluate of SCADA structure, where Remote Stations might be an Electric Substation. With progress within digital computing vicinity, mixing of virtual clever electronics gadgets play a tremendous position inside industrial production, in which manufacturing factory use PLCs/RTUs to govern gadgets, and broaden distributed as well as large complex structures wherein clever systems are part of the producing plant manipulate systems. Most often, an SCADA gadget will reveal and make mild changes to characteristic optimally.

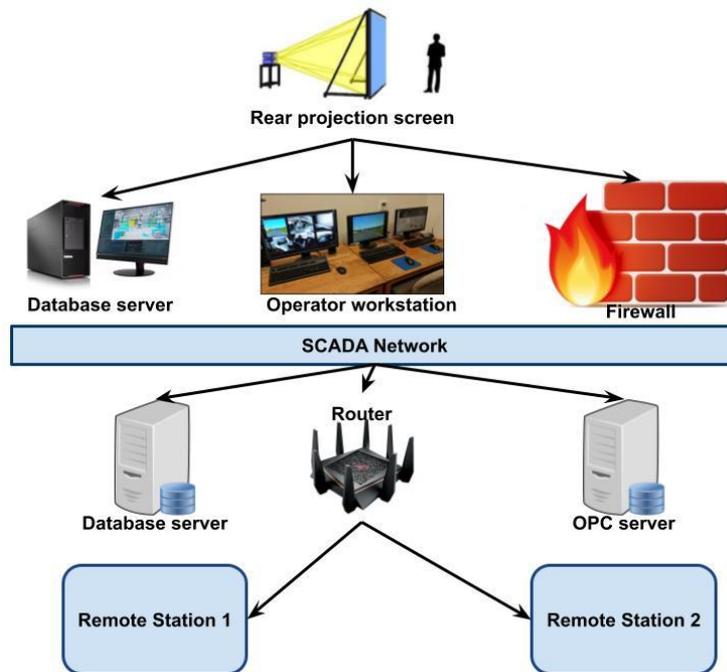


Figure-2 Architecture of SCADA

SCADA empowers the power consumer by interconnecting strength management systems to authorize the client to manipulate their personal demand of energy as well as manipulate prices. It allows grid to be self-healing by means of mechanically responding to power nice troubles, strength outages, and strength device faults. SCADA optimizes grid property by using monitoring and optimizing the ones assets at the same time as less operations as well as preservation expenses. SG, intelligence and manage want to exist along entire energy deliver chain. This consists of energy generation as well as transmission from starting to shipping cease-factors on the patron's aspect and consists of each fixed and cell gadgets within the SG architecture.

One of the important thing approaches of SCADA is the capacity to oversee an entire machine in real time environment. Which might be communicated at ordinary small time periods relying at the device. An SCADA method as an commercial automation method is utilized to gather facts from instruments as well as sensors located at far off websites and to receive/transmit records at master station central web page for either controlling or monitoring reason. Accumulated data from sensors as well as gadgets is generally regarded on one or extra SCADA host computer systems which are located at important web site. Based on obtained from far flung substations, automated or operator-driven supervisory instructions are pushed to far flung

substation manage gadgets, which might be generally known as outstation or area devices.

Consider a power gadget including N buses represented via set of nodes or vertices $\mathcal{V} = \{v_i\}_{i=1}^N$ and T transmission strains defined by means of set of edges $E \subset \mathcal{V} \times \mathcal{V}$. An part starting at node i and ending at node j is given with aid of $(v_i, v_j) \in E$. Digraph is known as related if there exists a node v_k is $v_j \in \mathcal{S}_k$ for $j = 1, \dots, N, j \neq k$ Such a node v_k is known as related node. Let $\mathcal{A} = [a_{ij}] \in \mathbb{R}^{N \times N}$ be a weighted adjacency matrix. Cost of $a_{ij} \geq 0$ represents coupling energy of area (v_j, v_i) . In addition, 0 is a simple eigenvalue of L , if and best if G is a linked digraph. We would really like to name interest to truth that similar situations at eigenvalues of L may be acquired via other residences of G . For a strength device running in steady-nation, with negligible admittance at each department, actual energy injected at bus i [71] is given as eqn (12)

$$P_i = V_i \sum_{j \in \mathcal{N}_i} V_j b_{ij} \sin(\theta_i - \theta_j). \quad (12)$$

Based on our existing discussion, modern-day electricity structures typically encompass era units and hundreds which might be continually added and/or eliminated. We count on that energy gadget is really operating in a quasi-regular-kingdom, wherein voltage phase angles at every bus are converting slowly as well as randomly.

Monitoring for malicious activities using supervised radial basis fuzzy systems (SRBFS):

Let characteristic $f(X)$ be a mapping from X to Y , in which $X = (x_1; \dots; x_p)$ is a p -size real vector is independent, or enter, variables of gadget, and Y is a fuzzy wide variety. Preferred fuzzy regression method may be given as eqn (13)

$$Y = f(X) \{+\} \epsilon \quad (13)$$

Data fusion as well as fuzzification processing of multichannel enter alerts have been performed within the SRBFS layer, club degree output. Fuzzy category of input alerts turned into accomplished within the output unit. Output of j th SRBFS is then represented by using eqn (14)

$$h_j(X(t)) = \frac{1}{1 + \exp(-a(-d_p^2(x(t), Z_j(t))/\sigma_j^2) - c)} \quad (14)$$

in which $Z_j(t)$ is kernel center vector in j th FRBN. Term $dv(X(t), Z_j(t))$ is space between $X(t)$ and $Z_j(t)$, primarily depends on a some norm, and $\sigma > \text{zero}$ is a smoothing specification. It can be evaluated as follows by eqn (15):

$$\tilde{y} = F(\tilde{X}(t)) = \sum_{j=1}^m \tilde{w}_j \cdot h_j(\tilde{X}(t)) \quad (15)$$

M_k is quantity of pattern subclasses within k th pattern elegance. FR phrases are nodes in fuzzy rule layer units as well as T-S is a fuzzy classifier.

Enter layer takes a multichannel time-varying sign $X(t) = (x_1(t), x_2(t), \dots, x_n(t)) (t \in [0, T])$. (2) In RFFL, FRBNs are utilized because fuzzy set membership capabilities as well as exponential sigmoid is utilized to radial foundation kernel feature. Output of $X(t)$ on j th node in this layer may be given as follows by eqn (16):

$$\mu_{A_j}(X(t)) = \frac{1}{1 + \exp(-a(-d_p^2(x(t), Z_j(t))/\sigma_j^2) - c)} \quad (16)$$

where A_j is popular fuzzy set, μ_{A_j} is membership characteristic for A_j , $Z_j(t)$ is kernel middle sign vector, σ_j is an FRBN smoothing specification, and $j = 1, 2, \dots, n_i$. N_i is quantity of samples inside i th pattern subclass. Kernel center functions for FRFN were decided usage of the following method.

(1) Multichannel time-various signal sample sets, containing K pattern instructions, had been utilized as input. DTW set of rules [29], which is insensitive to contraction as well as extension of time-various signals, become utilized to degree similarity between signal sample capabilities. DFCM clustering method [30] changed into then utilized to divide samples from every pattern elegance into subclasses exhibiting comparable traits, earlier than deciding on ordinary samples from each. +e k th pattern elegance become divided into $m = \sum_{k=1}^K m_k$ walls and sample set consist of total of $m_k (k = 1, 2, \dots, K)$ m_k sample subclasses. $Z_{kl}(t)$

terms are sequentially given as kernel facilities for every node in RBFPN layer, with m general nodes within FRBN. Structural as well as statistics constraints had been then produced via embedding of previous function expertise.

(3) Regularization layer I normalized outputs of FRBN layers, that is given as eqn (17)

$$\mu'_{A_{ij}}(\tilde{X}_i) = \frac{\mu_{A_{ij}}(X_i)}{\sum_{j=1}^n \mu_{A_{ij}}(X_i)} \quad (17)$$

where $\mu_{A_{ij}}(X_i)$ is regularized output of $\mu_{A_{ij}}(X_i)$. +e FRBNs have been utilized as parameterized club capabilities as well as membership diploma of enter signal, relative to bushy set, become adaptively found by using studying instance pattern set. Fuzzy rule layer connects antecedent as well as belief nodes. Connection policies needed that every rule node was linked best to a regular node from every enter. In class issue, fuzzy units based on to pattern subclasses had been same as pattern classes. In K -type trouble, variety of fuzzy sets was given by means of K . FRBN layer outputs are in step with pattern subclass fuzzy set, quantity of nodes in guideline layer is represented by eqn (18),

$$L = K^m \quad (18)$$

Connection regulations as well as connection techniques can also fluctuate and range of nodes and era rules in guideline layer will range. Utilizing fuzzy multiplication, output of k th rule node is given as eqn (19),

$$z_k = \prod_{i=1}^n \mu'_{A_{ik}}(\tilde{X}_i) \quad (19)$$

wherein different T-everyday operators that carry out fuzzy “and” operations is utilized in fuzzy multiplication.

(5) Regularization layer II strategies outputs of fuzzy rule layer. Output of l th node in this layer is taken into consideration activation intensity of l th rule.

(6) T-S fuzzy classifier accepts L normalized rule activation intensity q_1, q_2, \dots, q_L , output by means of regularization layer II, as enter. Output of T-S fuzzy classifier is then represented with aid of eqn (20)

$$\tilde{y} = \tilde{f}(\sum_{k=1}^L (\tilde{w}_k q_k + r_k)) \quad (20)$$

wherein f is activation feature for classifier and $w = k$ and r_k are classifier specifications

Inputs of FRBF network are nonfuzzy. Active function in every hidden unit is a Gaussian feature by eqn (21)

$$h_j(X) = \exp \left[- \left(\frac{\|X - v_j\|}{\sigma_j} \right)^2 \right] \quad (21)$$

in which, $X = (x_1; \dots; x_p)T$ is enter vector; v_j is a p -dimensional center and σ_j is width Output of community is a made from hidden layer output as well as connection weight by eqn (22):

$$f(X) = \sum_{j=1}^c h_j(X) w_j \quad (22)$$

in which, w_j is connection weight among output layer, which is a single node, and j th hidden unit, and $w_j = (a_j; b_j)$ is a symmetric triangular fuzzy wide variety. Output decided by way of Eq. (eight) is in addition normalized by eqn (23)

$$\bar{f}(X) = \frac{\sum_{j=1}^c h_j(X)w_j}{\sum_{j=1}^c h_j(X)} \quad (23)$$

We will use (nine) as final network output. Training of FRBF community is executed by means of usage of a hybrid getting to know approach, which mixes self-organized studying and supervised getting to know. The gaining knowledge of parameters within hidden gadgets is self-organized mastering as well as getting to know of connection weights is supervised.

4. Experimental analysis:

To take a look at the proposed offerings, a pattern distribution grid, composed of a 15kV 485 MV grid and 400V LV grids, are rivaled in simulation environment. Utilized grid is composed of buses on MV facet, of which one is primary HV/MV substation, nine are nodes linked to MV/LV 488 substations imparting residential masses, are business masses connected to MV stage and one is a era plant, additionally directly related to MV. In subsequent checks, a constraint on radial operation of grid is assumed. One of the branches is taken into consideration as generally open as well as this represents a reference situation for tests. To check Network Topology Reconfiguration carrier, however, possibility to open/close any of MV lines is taken into consideration.

Table-1 Comparative analysis based on control system in smart grid

Parameters	OREM	RSEFNN	SGWC_5G_REM
Scalability	55	60	65
QoS	61	65	71
Power consumption	55	45	41
Network Efficiency	85	88	92

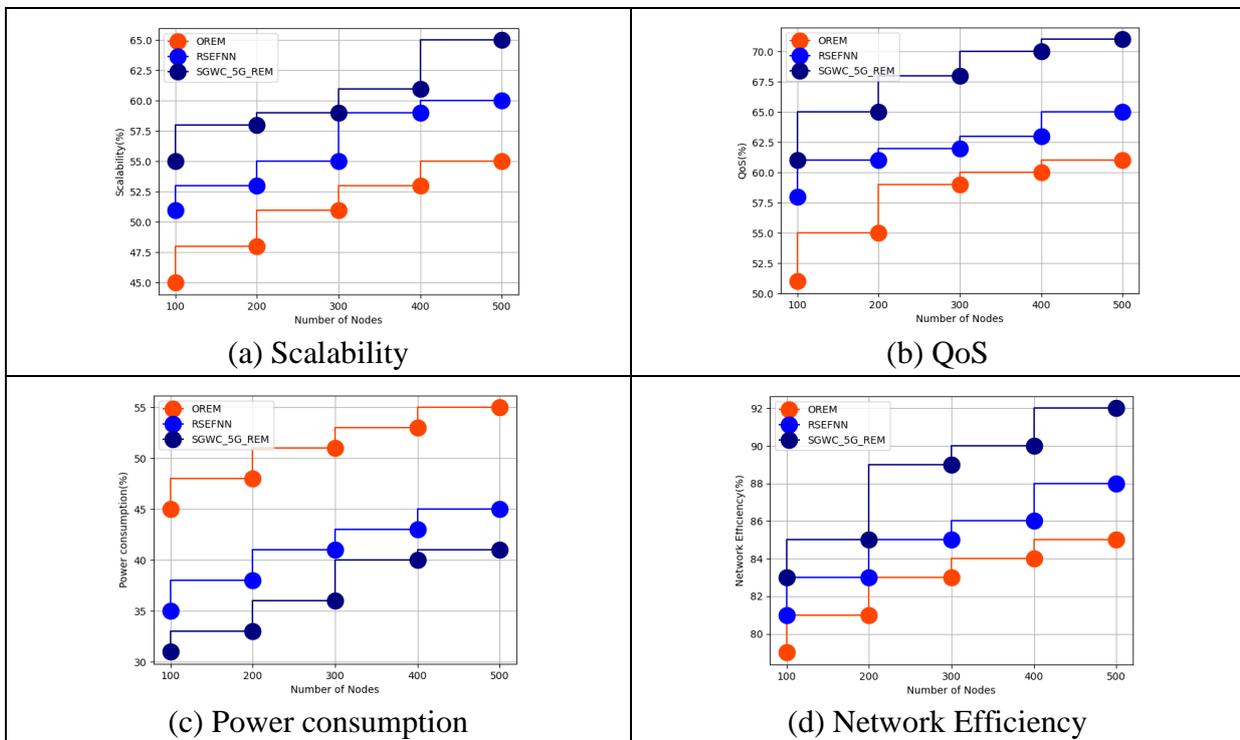
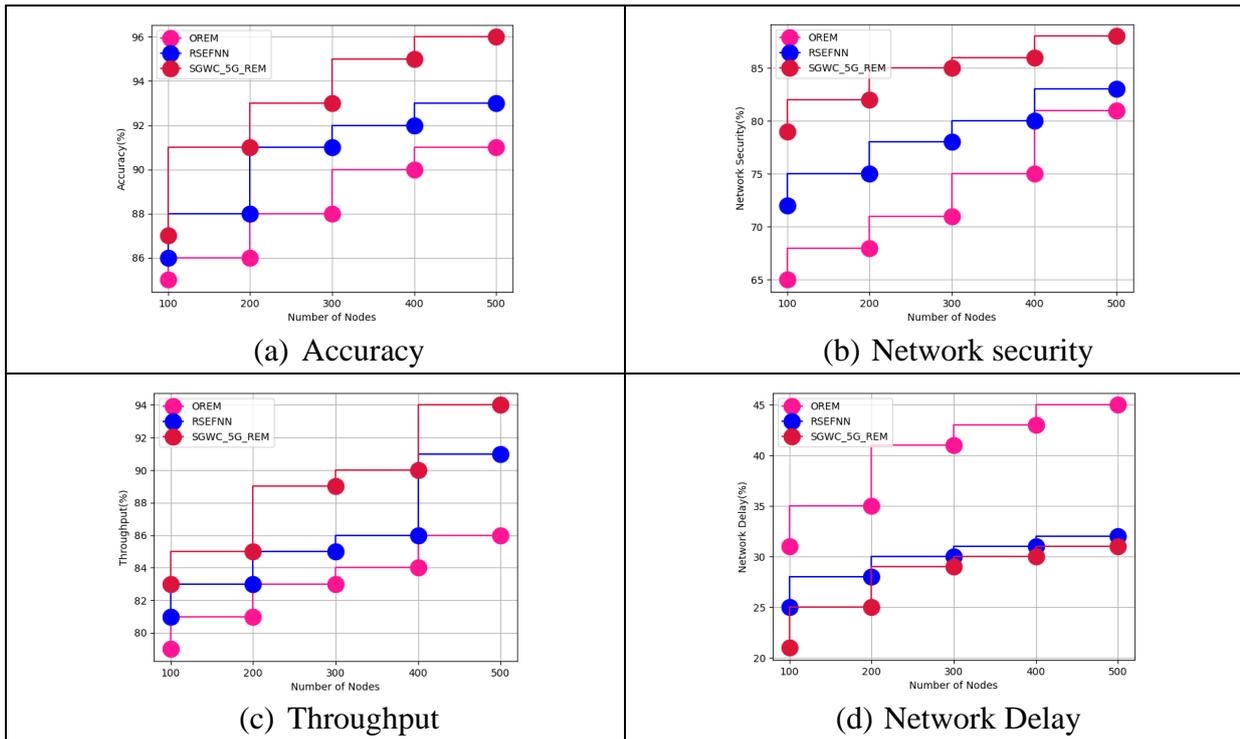


Figure-3 Comparative analysis of control system in terms of (a) Scalability, (b) QoS, (c) Power consumption, (d) Network Efficiency

Table-2 Comparative analysis based on monitoring system in smart grid

Parameters	OREM	RSEFNN	SGWC_5G_REM
Accuracy	91	93	96
Network Security	81	83	88
Throughput	86	91	94
Network delay	45	32	31



The above table-2 and figure-4 (a)- (d) shows Comparative analysis based on monitoring system in smart grid in terms of (a) accuracy, (b) network security, (c) throughput, (d) Network delay. The discrepancy between the obtained result and the actual result—also known as bias—which may be positive or negative—determines accuracy. How accurately a value is stated refers to how close it is to the actual, true value being described. Rounding, the use of significant figures, and specific units or measurement ranges can all have an impact on accuracy. The process of creating, putting into place, and ensuring security on a WCN is known as network security. WCN is further protected by this subset of network security. Wireless security is another name for wireless network security. In order to prevent unwanted people from accessing your wireless network as well as stealing data utilising your Wi-Fi network, you must implement wireless security. In more specific terms, wireless security guarantees that a Wi-Fi network is shielded from illegal access. The actual amount of data that is

successfully transferred or received across the communication link is known as throughput. A number of technical factors, like as delay, packet loss, jitter, and more can cause throughput—which is displayed as kbps, Mbps, or Gbps—to differ from bandwidth. the total number of objects the system created or processed during the specified time frame. This is 1,000 things spread over 100 time units in the example with two components. The total number of things each component processed or produced (block). A signal's propagation time from one end of the circuit to the other is measured by the concept of delay. In nanoseconds, network propagation latency is measured (nS). Category 5e UTP typically has a propagation delay of somewhat less than 5 nS per metre. Transmission delay is the length of time it takes to place a data packet on a transmission network. Mathematically, Transmission delay \propto Length / Size of data packet. Transmission delay \propto 1 / Bandwidth. From above analysis the proposed technique attained accuracy of 96%, network security of 88%, throughput of 94%, Network delay

of 41% when compared to existing technique in monitoring system based on proposed technique.

5. Conclusion:

In this research the novel framework has been designed for smart grid communication in wireless 5G networks for monitoring and controlling management. The smart grid control management has been carried out by designing Stackelberg equilibrium based SCADA (supervisory control and data acquisition) system. Where the experimental results obtained for control system is Scalability of 65%, QoS of 71%, Power consumption of 41%, Network Efficiency of 92%. Then the smart grid monitoring has been carried out using supervised radial basis fuzzy systems. While the results obtained for this monitoring system based on proposed technique is accuracy of 96%, network security of 88%, throughput of 94%, Network delay of 41%. The power grid can be made more dependable, adaptable, efficient, and durable through the use of smart grid technology, which integrates electrical, informational, and communication technologies. It is an intelligent PG that incorporates a variety of renewable and alternative energy sources. Key components of a SG implementation include automated monitoring, data collecting, control, and developing communication technologies. The future scope for this research can be carried out in implementing the designing of controlling and monitoring system for industrial application and manufacturing.

Reference:

- [1]. Alshehri, K., Liu, J., Chen, X., & Başar, T. (2015, December). A Stackelberg game for multi-period demand response management in the smart grid. In *2015 54th IEEE Conference on Decision and Control (CDC)* (pp. 5889-5894). IEEE.
- [2]. Huang, L., Xu, S., Liu, K., Yang, R., & Wu, L. (2021). A Fuzzy Radial Basis Adaptive Inference Network and Its Application to Time-Varying Signal Classification. *Computational Intelligence and Neuroscience*, 2021.
- [3]. Abdrabou, A. (2014). A wireless communication architecture for smart grid distribution networks. *IEEE Systems journal*, 10(1), 251-261.
- [4]. Almasarani, A., & Majid, M. A. (2021). 5G-Wireless sensor networks for smart grid-accelerating technology's progress and innovation in the kingdom of Saudi arabia. *Procedia Computer Science*, 182, 46-55.
- [5]. Borgaonkar, R., Anne Tøndel, I., Zenebe Degefa, M., & Gilje Jaatun, M. (2021). Improving smart grid security through 5G enabled IoT and edge computing. *Concurrency and Computation: Practice and Experience*, 33(18), e6466.
- [6]. Wang, D., Wang, H., & Fu, Y. (2021). Blockchain-based IoT device identification and management in 5G smart grid. *EURASIP Journal on Wireless Communications and Networking*, 2021(1), 1-19.
- [7]. Taik, A., Nour, B., & Cherkaoui, S. (2021). Empowering prosumer communities in smart grid with wireless communications and federated edge learning. *IEEE Wireless Communications*, 28(6), 26-33.
- [8]. Chafi, S. E., Balboul, Y., Mazer, S., Fattah, M., & El Bekkali, M. (2022). Resource placement strategy optimization for smart grid application using 5G wireless networks. *International Journal of Electrical & Computer Engineering* (2088-8708), 12(4).
- [9]. Ahmadzadeh, S., Parr, G., & Zhao, W. (2021). A review on communication aspects of demand response management for future 5G IoT-based smart grids. *IEEE Access*, 9, 77555-77571.
- [10]. Borenius, S., Hämmäinen, H., Lehtonen, M., & Ahokangas, P. (2021). Smart grid evolution and mobile communications—Scenarios on the Finnish power grid. *Electric Power Systems Research*, 199, 107367.
- [11]. Lu, G., Tian, L., Liu, H., Zhu, H., Wang, L., & Zeng, J. (2021, November). Research on the Application of Uninterrupted 5G Private Network in Smart Grid. In *Journal of Physics: Conference Series* (Vol. 2078, No. 1, p. 012062). IOP Publishing.
- [12]. Liu, Y., Yang, X., Wen, W., & Xia, M. (2021). Smarter Grid in the 5G Era: A Framework Integrating Power Internet of Things with a Cyber Physical System. *Frontiers in Communications and Networks*, 23.
- [13]. Abrahamsen, F. E., Ai, Y., & Cheffena, M. (2021). Communication technologies for smart grid: A comprehensive survey. *Sensors*, 21(23), 8087.
- [14]. Yuqing, Z. (2022). A Hybrid Convolutional Neural Network and Relief-F Algorithm for Fault Power Line Recognition in Internet of Things-Based Smart Grids. *Wireless Communications and Mobile Computing*, 2022.
- [15]. Lopez, J., Rubio, J. E., & Alcaraz, C. (2021). Digital twins for intelligent authorization in the B5G-enabled smart grid. *IEEE Wireless Communications*, 28(2), 48-55.
- [16]. Biswas, S. (2021). Development of Microcontroller Based Smart Grid Framework. *arXiv preprint arXiv:2111.10835*.
- [17]. Sathya, M., Gunalan, K., Anil Kumar, T. C., Shafi, S., & Johncy, G. (2021). An intellectual procurement innovation of smart grid power system with wireless communication networks based on machine



learning. *International Journal of Nonlinear Analysis and Applications*, 12(2), 1567-1576.

- [18]. Li, Q., Tang, H., Liu, Z., Li, J., Xu, X., & Sun, W. (2021). Optimal resource allocation of 5G machine-type communications for situation awareness in active distribution networks. *IEEE Systems Journal*.
- [19]. Muhammad, G., & Hossain, M. S. (2021). Deep-Reinforcement-Learning-Based Sustainable Energy Distribution for Wireless Communication. *IEEE Wireless Communications*, 28(6), 42-48.
- [20]. Sun, H., Li, G., Zhai, M., & Lu, W. (2022, April). Research on Smart Grid Heterogeneous Communication System Integrating Power Line Communication and 5G Communication. In *2022 7th Asia Conference on Power and Electrical Engineering (ACPEE)* (pp. 965-969). IEEE.

