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Smart Grid Sensor Monitoring Based on Deep Learning Technique with Control System Management in Fault Detection

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Abstract

The smart grid environment comprises of the sensor for monitoring the environment for effective power supply, utilization and establishment of communication. However, the management of smart grid in the monitoring environment isa difficult process due to diversifieduser request in the sensor monitoring with the grid-connected devices. Presently, context-awaremonitoring incorporates effective management of data management and provision of services in two-way processing and computing. In a heterogeneous environment context-aware, smart grid exhibits significant performance characteristics with the grid-connected communication environment for effective data processing for sustainability and stability. Fault diagnoses in the automated system are formulated to diagnose the fault separately. This paper developed anoptimized power grid control model (OPGCM) model for fault detection in the control system model for grid-connected smart home appliances. OPGCM model uses the context-aware power-awarescheme for load management in grid-connected smart homes. Through the adaptive smart grid model,power-aware management is incorporated with the evolutionary programming model for

	context-awareness user communication. The OPGCM modelperforms fault diagnosis in the grid-connected control system initially, Fault diagnosis system comprises of a sequential process with the extraction of the statistical features to acquirea sustainable dataset with effective signal processing. Secondly, the features are extracted based on the sequential process for the acquired dataset with a reduction of dimensionality. Finally, the classification is performed with the deep learning model to predict or identify the fault pattern. With the OPGCM model, features are optimized with the whale optimization model to acquire features to perform fault diagnosis and classification. Simulation analysis expressed that the proposed OPGCM model exhibits ~16% improved classification accuracy compared with the ANN and HMM model. ***Keywords: Smart Grid, Appliances, Fault Detection, Classification, Context Awareness, Feature Extraction***

1. Introduction

Smart Grid is a high level and modernized electrical framework with additional upgrades to the customary power network. The term was first presented by Andres E. Carvallo at a Global Information Enterprise (IDC) meeting in the extended time of 2007 at Chicago. In his show, the savvy network is portrayed as a mix of energy, correspondence, and programming with equipment, alongside the controlling frameworks with information conveyance, stockpiling, and use [1]. It has the capacity to get more productivity, security, dependability and simple upkeep. The mechanization of matrix exercises and quick solid remote two way correspondence through savvy meters and conveyance lines used to accomplish this in the brilliant lattice. Energy utilization necessities are tremendous in the ongoing advancement under numerous conditions to make due in this human world. The energy prerequisites and utilization can cause worldwide natural changes and shows impact on the use. Be that as it may, there is a benefit of utilizing environmentally friendly power sources like breeze, flowing, hydro. The shrewd network is an improved answer for create, transport and dispersions perspectives under proficient power the board [2]. The efficient power management process uses more secure two-way or bidirectional communication architecture to coordinate among the components of smart grid from generation to distribution. The smart meter is a main component with Advanced Metering Infrastructure (AMI). AMI is an integration of various automated hardware equipment like different types of smart grid sensors, and smart meters and other supported systems. In Canada, there is a huge project has been deployed with rich set of smart meters [3]. The communication process mainly required scalability of the network, security, reliability and quality of service are as the main parameters.

Dynamic pricing varies with the time and current power consumption. Peak demand is One of the major challenges of smart grids is peak demand [4]. The solution might not easy in this scenario. The producers or power generation systems needs to improve its capacity by at least 20% to the current state. Another side of coin is low usage of power; the generated power will get wasted if there is no huge demand. Since, there is no chance to save the generated power from grid; all the generated power will get wasted. The advanced smart grid systems will resolve those problems by maintaining dynamic pricing scheme. Dynamic pricing scheme is a process of changing prices according to real-time usage of power [5]. Normally, high cost during the high-peak hours and low cost at off-peak hours. The customers' needs to change plans according the dynamic pricing, this process reduce the overall burden to the power generators and distributors. Customers feel little no satisfaction with this procedure, but reduced power bills is effective. By considering the peak demand and dynamic pricing challenges, we proposed a model for efficient context aware power management scheme to enhance the efficiency in the usage for the customers. The load management process done at customer side, the customer needs to shift load times for appliances. This process works by delaying the appliance activities like forward the time for laundry to off peak hours and pre cooking, pre heating or pre cooling the stuff, etc. Energy storage can solve the problem by maintaining micro grids. The micro grid is not an ideal choice for all the consumers [6]. Those load balancing challenge by providing a model with the help of context aware system. Providing an efficient information management model solves the problem in the information management. In general, in the smart grid system huge set of data is being produced in every day usage. To provide the better services to the customers or users, the personalized context needs to be created in order to produce reliable services.

Fault detection is the most common way of noticing the deliberate framework information and framework status data and contrasting them and an ordinary scope of noticed properties to decide if a few estimations fall outside the reach addressing the sound state of the framework. Tragically, nobody method can identify all machine deficiencies. Notwithstanding, it has been proposed that vibration estimation, which is the most generally involved CM method in industry, can precisely recognize 90% of all hardware disappointments by the adjustment of vibration signals which they produce and the degree of sign can give an exact forecast of future disappointment [7].The errand is to analyze the shortcoming at a beginning phase so remedial move can be made as soon as conceivable to broaden the existence of the machine. Stuff and bearing parts assumes a significant part in a large number of the modern pivoting and transport hardware applications. Early shortcoming analysis of stuff and direction might forestall superfluous disappointments of the majority of the turning hardware framework and there by increment functional unwavering quality and accessibility of machine and issue finding strategies are significant for screen the circumstances in bearing and stuff. A powerful and technique must be explored and mechanized framework must be produced for modern hardware part wellbeing indicative exercises. In [8] examined the unique execution of the turning parts is profoundly powerful in the exhibition of any pivoting apparatus. The improvements in electronic information obtaining hardware, sensors, PCs and programming made a robotized management framework in condition checking of machines [9]. The significance of stuff and orientation in the modern pivoting and transport apparatus applications. In this way the computerized bearing and stuff part condition checking strategies got the significance in the field of examination [10].

In these new years, public power enterprises of different nations from Asia, Europe and others are showing a great deal of interest in the difference in current power matrix framework to new time of cutting edge smart correspondence framework. Also, extensive variety of exploration is happening at different sub degrees of brilliant framework correspondence framework [11]. The savvy framework structure follows the progressive configuration; numerous activities should be performed to accomplish the smooth stream from power age unit to the client utilization alongside control spaces for handling the essential activities to client information the board. The reason for almost 90% of all blackouts happening because of the dissemination organization and manual treatment of tasks [12]. Alongside that non-renewable energy source utilization and cost that prompts the failure of service organizations to grow their age limit in lined up with the rising interest for power. Different principles assists with making fitting and play shrewd network parts like ANSI C12.22 manages brilliant metering and IEC 61850 for computerizations of substations. There is an essential need of middleware framework for handling demands from different sources of info, which incorporates the sensors organizations, satellite interchanges, Wi-Fi and other conceivable remote organizations. Every one of the information ought to be the contribution to the middleware framework to powerfully handle the client level applications. The nature of administration and client fulfillment is extreme objective to the specialist organizations. Consequently, the job of middleware is urgent to accomplish the significant level middleware handling. Setting mindful framework should be intended to explicit middleware engineering to acquire our objective [13].

In this paper proposed a optimized power grid control model (OPGCM) model for the load balancing and classification for fault diagnosis in the smart grid appliances. The model uses the whale optimization model for the extraction of features and classification is performed with the deep learning model for the fault diagnosis. Simulation analysis expressed that proposed OPGCM model achieves the higher accuracy of 99% which is significantly higher than HMM and ANN model. The paper is organized as follows: Section 2 presented the related works for the fault diagnosis and smart grid. The section 3 and 4 provides the research methodology adopted for OPGCM with the optimization based deep learning. Section 5 provides the simulation results and overall conclusion is presented in Section 6.

2. Related Works

In [14] analyzed the most ordinarily involved vibration examination techniques for mechanical issue determination like time area examination, recurrence space investigation; time recurrence investigation for deformity identification in course. To portray the vibrations estimated from direction subject to different stacking conditions and with absconds situated on any bearing parts. They have decided the intermittent qualities of different stacking, transmission way and their effect on the vibration abundancy.

In [15] contends that Fourier examination gives an unfortunate portrayal of signs very much confined in time in light of the fact that the FFT expects to be a fixed sign and contains no data on when an occasion happened. The article involved the WT for of separating time recurrence data from the vibration signal. A survey on hardware diagnostics and prognostics executing Condition Based Support (CBM) in mechanical frameworks and accentuation on models, calculations and advancements for information handling and upkeep decisionmaking. They finish up with a concise conversation on current practices and conceivable future patterns of CBM. In [16] fluctuated the imperfection size and concentrated on its impact on vibration reaction. Creators have seen that the vibration plentifulness increments with deformity size. The dynamic model of profound score metal roller in presence of deformities on both of races under consistent and dynamic 9 stacking condition. They have reasoned that the adequacy of vibration speed in the event of numerous deformities is more when contrasted with single imperfection on one or the other race. Albeit, the deformity recognition for numerous imperfections is troublesome because of same vibration spectra as single imperfection.

In [17] proposed a procedure in view of interpretation invariant de noising and HHT to recognize moving component bearing shortcomings from solid foundation commotion. The sums up the turn of events and utilization of Hilbert-Huang Change for taking care of the issue of moving bearing shortcoming conclusion from a few viewpoints and summarizes the commonsense relevance of HHT strategy through the examination of moving bearing shortcoming finding with different techniques. A mixture approach for shortcoming determination of planetary course (with cultivated bearing deficiencies) utilizing an inner vibration sensor and novel sign handling procedures.. High level sign handling strategies, including Cepstrum brightening, Least Entropy Deconvolution (Drug), Otherworldly Kurtosis (SK) and envelope investigation were applied.

In [18] examined about the Condition observing of key parts in pivoting machines, for example, gearboxes guarantee decrease in expensive unscheduled machine down time and investigates the chance of checking cultivated surrenders on worm gears with vibration examination. Dissimilar to different sorts of gearboxes, observing of worm gearboxes isn't generally reported. The applied bispectrum to the investigation of helicopter gearbox vibration. The tops in the bispectrum along the symphonious lattice frequencies can be made sense of by the adjustment peculiarities connected with the neighborhood imperfection of stuff.

In [19] involved meter information coordination as middleware layer, "it is utilized for binding together the High level Metering Foundation (AMI) and Disseminated administration frameworks (DMS)" and they manage the correspondence conventions and data models. It addresses the interoperability issue and has serious level of dependability. It doesn't have the ability for any additional semantic worth to the data because of different information nature. WitjIAP-INMS, which is a product design for disseminated frameworks that proposes the "occasion based continuous middleware engineering" to trade information among various specialists.

The environmentally friendly power assets acquired notoriety overall in the space of dispersed age. The power issue is tended to by empowering the huge scope environmentally friendly power assets and gave an option in contrast to the regular age practices of power concentrated in [20]. The acquaintance of energy informatics in with the field of power rolled out extreme improvements given in [21]. It incorporates examination, plan and execution of models for working on the proficiency of energy interest.

Various operations that can be performed on the smart grid data is like storage, indexing, aggregation, clustering, sampling, searching and auditing. The storage of information at servers or may use cloud. Efficient algorithms required for making the indexing process and data aggregation is important for doing the batch processing when huge set of data available. Clustering of data processing reduces the processing and memory requirements of the system and processes it in the form of modules. Sample data retrieval is necessary for doing the calculations and analysis of data at certain circumstances. Searching is a process of retrieving or mining the required data from sensitive set of smart grid information. The auditing process is required to maintain the logs of old data for performing important future operations.

3. Communication Model

In context management user inputs are collected in the optimized power grid control model (OPGCM) from the different sensor nodes integrated in the different smart home. In this context, OPGCM model perform configuration of load balancing through Evolutionary programming model. The load balancing is employed with the evolutionary programming to find optimal load balancing with the proactive manner based optimal load balancing with consideration of previous collected data. The OPGCM model perform load balancing for effective information required for the smart home integrated with smart grid model. The header fields consists of the neighboring node, time stamp, node id, energy requirement and usage. The figure 1 illustrated OPGCM model employed for the smart grid management in smart home applications.

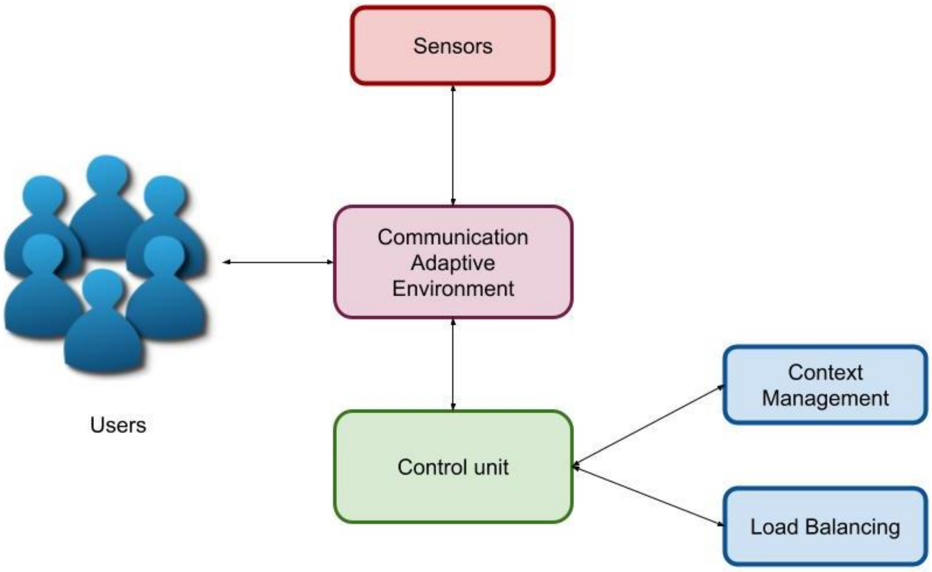

Figure 1: *Power Aware Energy Management*

The developed OPGCM model collects contextual information directly or indirectly based on behaviour pattern. Through adaptive pattern, environment context awareness generate the efficient energy-awaremechanism for the appliances. The concept associated with the context awareness are presented as follows:
Context Tuple: This comprises of two variables based on time stamp and context values. The collected information are from sensor, application software and devices. The data comprises of the time in system, intensity of light and rate of transmission application in smart grids. The measurement of context tuple are represented in equation (1)

$$X = < T, C_1, C_2, \dots \dots, C_n > \qquad (1)$$

Action Tuple: In context management the action tuple is considered as the important concept comprises of the two variables such as context tuple. The action variable $A_1, A_2, \dots\dots, A_n$ for the time T is evaluated using the equation (2)

$$Y = < T, A_1, A_2, \dots\dots, A_n > \quad (2)$$

Resulting Context: The smart home raw context tuples are processed in resultant evaluation using Context Expression. The expression in context format is evaluated based in the time as given in equation (3)

$$\{\forall, \exists\} Tin < time > (\{C, A\} < compare >< Value >) \quad (3)$$

The expression of context is evaluated based on the consideration of User L and M in the smart homes. The OPGCM model perform the energy consumption L and M in the smart grid sensors. The peak time energy consumption is evaluated with the user L based on appliances time. The context expression modelling is evaluated using the consideration of following equation
For any appliances peak load T lies in the range of {9-5} = true
Action_M_applicances<>"Start"
Action_M_appliances<>"Delay Time"

3.1 Load Balancing with OPGCM

Smart grid load balancing is considered as primary technique for the OPGCM control unit model through problem formulated as represented in equation (4)

$$Min \sum_{l=1}^{m} (l(t) - O(t))^2 \quad (4)$$

In above equation (4) the time t objective function is represented as $O(t)$ with the system loaf of $l(t)$ denoted in equation (5)

$$l(t) = f(t) + \alpha(t) - \beta(t) \quad (5)$$

Where, time t exhibits load forecasting value of $f(t)$ the load those are connected and disconnected are denoted $\alpha(t)$ and $\beta(t)$ in time t. The load that is connected in the system α(t) is examined in equation (6)

$$\alpha(t) = \sum_{l=1}^{t-1} \sum_{A=1}^{k} \gamma_{Ait} * P_{1A} + \sum_{u=1}^{t-1} \sum_{l=1}^{t-1} \sum_{A=1}^{k} \gamma_{Ai(t-1)} * P_{(1+u)A} \quad (6)$$

In above equation (6) the type of appliances is denoted as γ_{Ait} and shift in load is represented as A at the time i to t, the difference in appliances sample number is represented as k. The load shift in time power consumption is denoted as P_{1A} and $P_{(1+u)A}$ for the load step of $(1 + u)$. The power consumption in the appliances time duration are stated as type A.
The appliances time step maximal load is computed with the equation (7)

$$\delta = \left((24 - D) * D\right) * A^{-1} \quad (7)$$

The evolutionary process chromosome represented with consideration of bits with the transferredinformation in smart grid based smart home appliances. The representation of chromosome with time step δ is given in equation (8)

$$S(chromosome) = \delta * Number\ of\ bits \quad (8)$$

The proposed OPGCM model uses the evolutionary algorithm comprises of the optimal solution operation based on crossover, selection and mutation process. The selection process is performed with generation of the existing operator in the genetic process, mutation and selection. The population is generated based on cross over process with single point cross over to evaluate the fitness function based mutation process. The large mutation process provides the complex solution for convergence operation. The effective cross over rate measured for the OPGCM model is 0.9 for the mutation with the rate of 0.1. With the mid-peak time estimation smart grid connected environment uses the context aware routing protocol model with the identification of shortest path to perform routing. The algorithm implemented for the computation of OPGCM model for the data transmission in the smart sensor environment are presented as follows:

Algorithm 1: OPGCM for the effective routing

Begin
Compute Threshold value τ
Evaluate the delay in appliances δ
Initialize the appliances start time with START_REQ
if START_REQ = peak then
Incorporate δ delay based on off-peak value as ( )
If δ> τ then
Immediately initialize the appliances()
Else
Initialize delay ( )
End if
Else
If START_REQ_appliance = mid-peak then
Incorporate δ delay with off-peak ( )
If δ> τ then
Initialize the appliances immediately ( )
Else
Initialize delay ( )
End if
Else
Initialize appliances immediately ( )
End if
End if
End if
End

4. Wavelet Transformation for Fault Detection in Control System

To evaluate the feature to extract OPGCM model increases the accuracy through genetic algorithm techniques to minimize the fitness features. The classification input are minimized the data features to detect the misclassification to achieve the effective accuracy for the fault prediction. The OPGCM model uses the whale optimization model for the detection of fault detection as shown in figure 2.

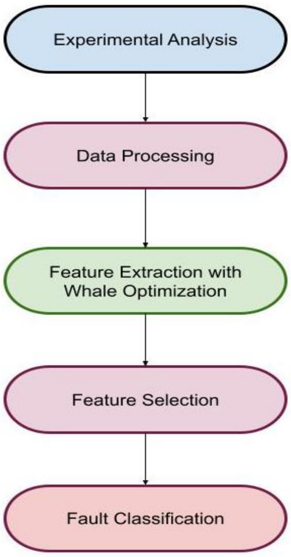

Figure 2: *Process in OPGCM*

The genetic algorithm based on OPGCM model computes the binary string length for every subset features. The value of gene is evaluated either as "0" or "1" to select the features or not. The weighted feature information are computed with the Ranking feature based population construction model. The OPGCM model uses the randomly generated with gene 10 features initial population. The chromosome fitness function are evaluated based on class distance is calculated with the equation (9)

$$J_c = \sum_{i=1}^{d} P_j J_i \tag{9}$$

The distance class is measured using the equation (10)

$$J_b = \sum_{i=1}^{c} p_i (m_i - m)^T (m_i - m) \tag{10}$$

In above equation (10), the class mean vector is represented as m and fitness value is computed as in equation (11)

$$J = J_i + \left(\frac{1}{J_b}\right) \tag{11}$$

The equation (9) – (11) provides the distance evaluation with the genetic evaluation based algorithm. The features are computed based on the computed distance to minimize the data feature classification rate. The OPGCM model process with the genetic algorithm is presented in figure 3.

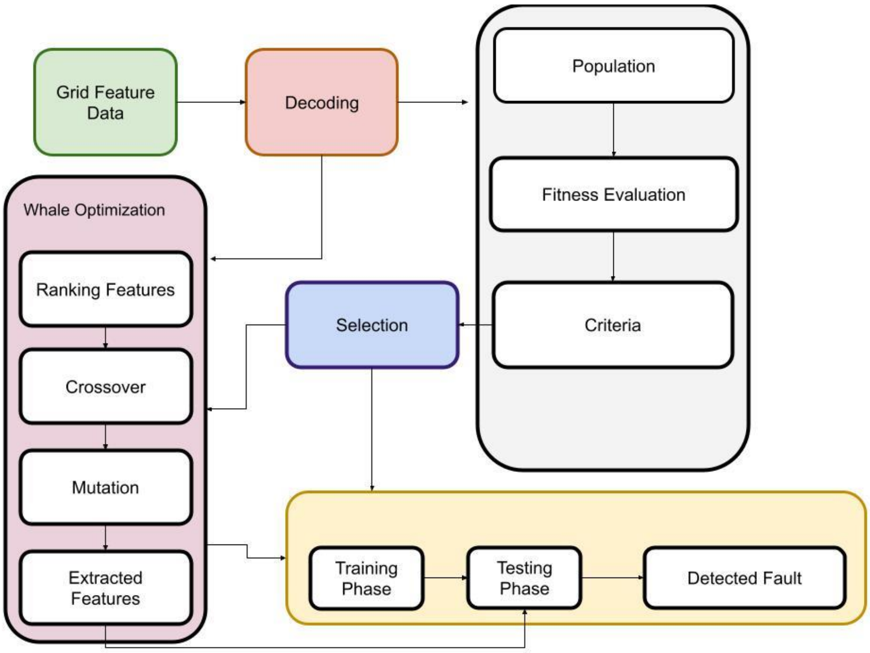

Figure 3: *Process in OPGCM*

Deep learning model comprises of three layers such as input, hidden and output layer with the feed forward sigmoid neurons based on input and output layer. The deep learning model-based features are computed with the back propagation algorithm with the neural network. The deep learning features are utilized for training and testing process. The three stages of training process are input feed forward, arithmetic operation to calculate error and modification of weight. The input layer comprises of neurons those are equal to features and neuron output layer are equal to states. However, their exists a certain challenge associated with the computation of neuron in the hidden layer. The OPGCM model features with deep learning model uses the nodes for input and output based on transfer function. The layer of input and output comprises of 10 features and classes count of 4 those are recognized with the Hidden layer neuron count. The hidden layer neurons are computed with the minimal error value for the input and output layer for data. The deep learning model comprises of 3 layers for the handling signals in the hidden layer features.

5. Results and Discussion

The proposed OPGCM architecture uses the five domain features for the testing process for the different appliances for the smart home connected through smart grid connection. With the consideration of different appliances electrical devices are computed with estimation of control system fault tolerance based on service and response time evaluated with the smart grid architecture model to detect fault tolerance in control system. The figure 4 presented a proposed OPGCM model power consumption level for the fault detection in grid connected control system. The evaluation is performed with consideration of centralize and middleware architecture model.

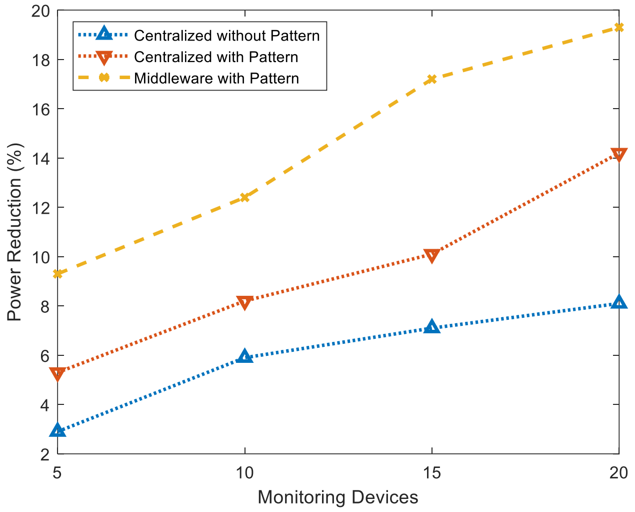

Figure 4: *Estimation of Power Reduction with OPGCM*

The performance of delay in data transmission in the smart grid are constructed with the shortest path route estimation. The figure 5 provides the computation of the routing performance for the OPGCM model based on consideration of shortest, Beacon and Implicit feature model.

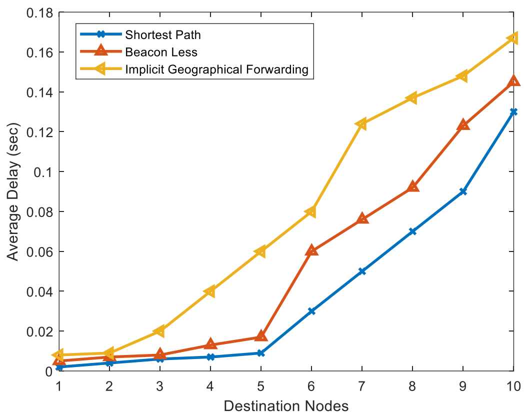

Figure 5: *Comparison of Delay*

Packet Loss Ratio (PLR) measure the number of lossesestimated for the total number of transmitted packets between the smart grid in the appliances. The figure 6 provides the packet loss ration measured for the disconnected devices in the sensor monitoring based control system.

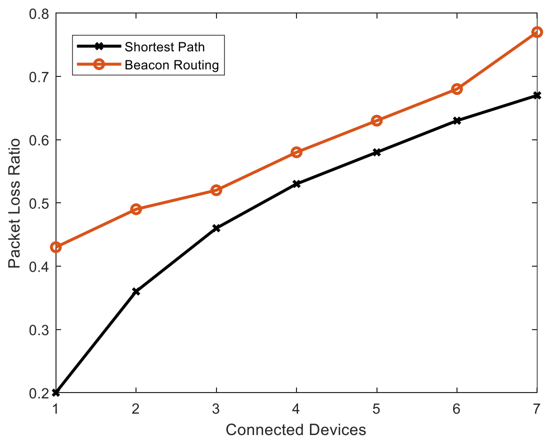

Figure 6: *Comparison of Packet Loss Ratio (PLR)*

The figure 6 provides the PLR measured for the routing performance with the shortest path and the disconnected devices in the network. The packet count transmitted between the source to destination those are not delivered is estimated. The appliances implemented in the smart grid environment for the smart home appliances for the power consumption is presented in table 1.

Table 1: *Appliances Power Consumption*

Appliances	Power Consumption (KWh)	Number of appliances
Washing Machine	0.6	119
Oven	0.3	198
Televisions	0.7	197
Cooker	0.8	54
Fan	0.9	198
Laptops	1.2	66
Vacuum cleaner	0.5	78
Air conditioners	4.6	148
Tube lights	2.3	249
Fans	3.4	238
Water dispenser	2.6	14
Water coolers	2.4	11
Coffee maker	1.9	21
Induction Motors	100	5
Motors	137	7
Heavy Operating Fans	28.9	13
AC	34	14
Water coolers	4	24
Welding machine	23	27
Water Heater	11.8	31

The OPGCM model uses the effective optimization of the reducing power consumption for the critical time and maintain effective load balancing for the residential, commercial and industrial regions as shown in figure 7, 8 and 9. The specified information about the power consumption factors are evaluated based on the load balancing.

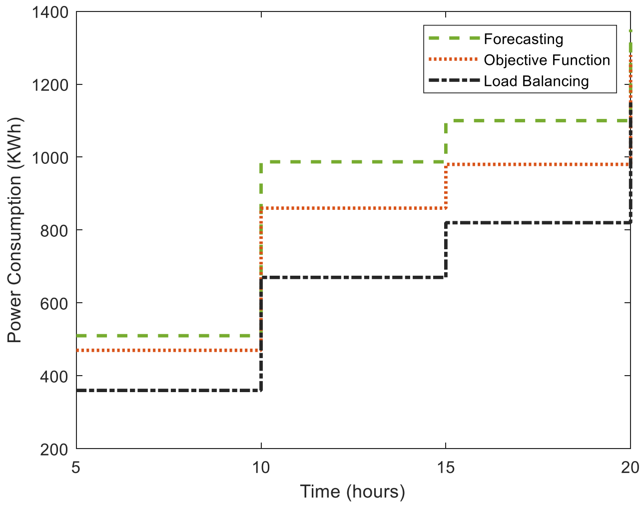

Figure 7: *Comparison of Residential Power Consumption*

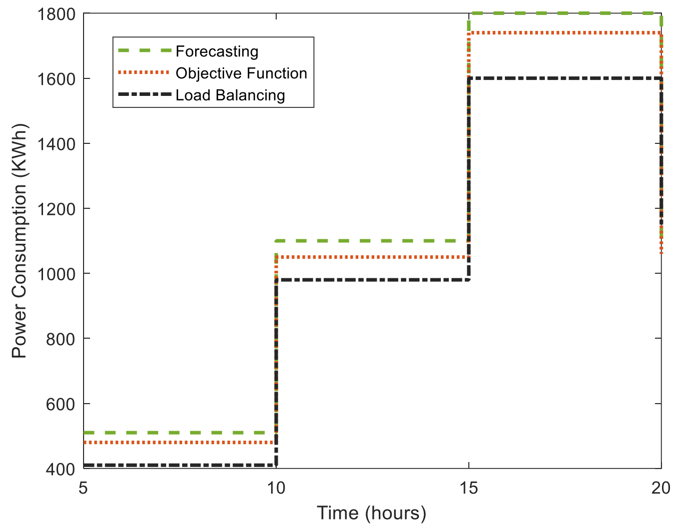

Figure 8: *Comparison of Commercial Regions*

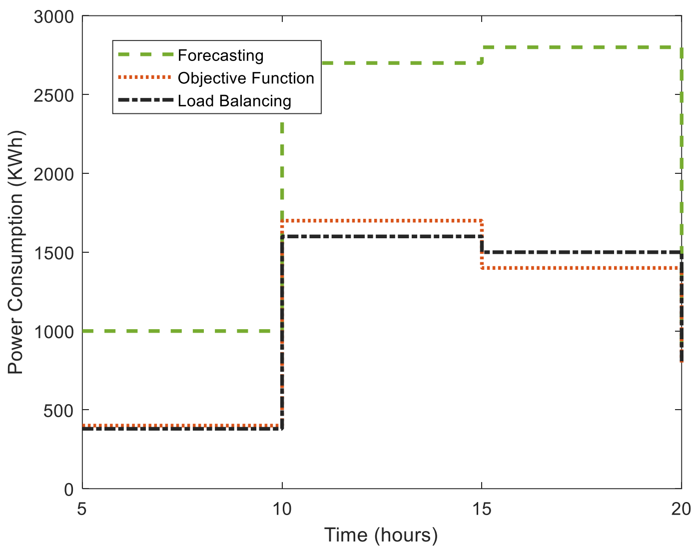

Figure 9: *Comparison of Industrial*

With proposed OPGCM model the results demonstrated that features selection or the fault detection classification accuracy is measured as the 99.67% and 99.84% for the training and testing phases with the cluster size of 4. The classification of fault detection in the control system for the data transmission with smart grid employed smart home are examined based on consideration of different cluster size and rules. The examination is performed with the consideration of training and testing process for accuracy measurement.

Table 2: *Classification Characteristic with OPGCM*

Features	Each class cluster	Training	Testing	Rule Count
ALL	1	98.9716	97.5948	4
2,4,5,6,7	1	99.3443	99.568	4
ALL	1	98.8547	98.4324	8
2,4,5,6,7	2	99.3572	99.8436	8
ALL	3	98.4544	98.4647	12

2,4,5,6,7	3	97.8935	97.6224	12
ALL	4	98.3467	98.3582	16
2,4,5,6,7	4	99.5677	99.373	16

With the OPGCM model the deep learning model compute the features of fault tolerance in the smart grid employed smart home appliances. The OPGCM model perform the model training and testing process for the input feature estimation in the smart grid model. The training data comprises of the 75% of sample and 15% were utilized for validation & testing. The evaluation is performed with the corresponding representation of data set 4 with consideration of different classes. The output target values are measured based on fault tolerance in the smart grid network with 1000 normal set and spalling error in 2^{nd} neuron as 0100, 3^{rd} neuron value is 0010 and 4^{th} neuron value as 0001. The deep learning OPGCM model features are validated with 15% with error estimation. OPGCM model features are measured with the generalized training process without testing network performance is affected. The table 3 provides the OPGCM model is comparatively examined with the HMM model with 70% training and 30% testing process.

Table 3: *Comparative Analysis*

Classification scheme	Training Accuracy (%)	Testing Accuracy (%)	Computational time(sec)
OPGCM (ALL) Cluster-1	98.9716	97.5948	36
OPGCM (2,4,5,6,7) Cluster-1	99.3443	99.568	41
OPGCM (ALL) Cluster-2	98.8547	98.4324	38
OPGCM (2,4,5,6,7) Cluster-2	99.3572	99.8436	34
OPGCM (ALL) Cluster-3	98.4544	98.4647	36
OPGCM (2,4,5,6,7) Cluster-3	97.8935	97.6224	31
OPGCM (ALL) Cluster-4	98.3467	98.3582	28
OPGCM (2,4,5,6,7) Cluster-4	99.5677	99.373	24
ANN(ALL)	89.5654	88.343	56
ANN(2,4,5,6,7)	83.5135	82.6326	78
HMM (ALL)	78.5622	77.8413	89
HMM(2,4,5,6,7)	74.3665	73.5821	93

The comparative analysis of proposed OPGCM model is evaluated with the consideration of different features and cluster compared with the ANN and HMM model. The training and testing accuracy of the OPGCM model is higher compared with the ANN and HMM model. The estimation of computational time expressed that proposed model exhibits the minimal time compared with the ANN and HMM model.

6. Conclusion

This paper developed a optimized power grid control model (OPGCM) for the faut tolerance in the smart grid implemented control system model. The OPGCM model comprises of the context aware scheduling for the optimization path estimation in the grid connected smart home applications.The power aware model exhibits the effective load management in the adaptive system for the different scenario such as residential, commercial and industrial applications. The developed OPGCM model uses the evolutionary based whale optimization model for the estimation of features and communication in the smart home application. The simulation analysis expressed that developed OPGCM model exhibits the effective load balancing for the user and grid connected environment. The comparative analysis expressed that proposed OPGCM model exhibits the ~ 16% improved classification performance for the fault tolerance in the grid connected environment with deep learning environment.

References

[1] Elsisi, M., Mahmoud, K., Lehtonen, M., & Darwish, M. M. (2021). Reliable industry 4.0 based on machine learning and IOT for analyzing, monitoring, and securing smart meters. *Sensors*, *21*(2), 487.

[2] Rivas, A. E. L., & Abrao, T. (2020). Faults in smart grid systems: Monitoring, detection and classification. *Electric Power Systems Research*, *189*, 106602.

[3] Kotsiopoulos, T., Sarigiannidis, P., Ioannidis, D., & Tzovaras, D. (2021). Machine learning and deep learning in smart manufacturing: The smart grid paradigm. *Computer Science Review*, *40*, 100341.

[4] Cui, L., Qu, Y., Gao, L., Xie, G., & Yu, S. (2020). Detecting false data attacks using machine learning techniques in smart grid: A survey. *Journal of Network and Computer Applications*, *170*, 102808.

[5] Ibrahim, M. S., Dong, W., & Yang, Q. (2020). Machine learning driven smart electric power systems: Current trends and new perspectives. *Applied Energy*, *272*, 115237.

[6] Kawoosa, A. I., & Prashar, D. (2021, January). A review of cyber securities in smart grid technology. In *2021 2nd International Conference on Computation, Automation and Knowledge Management (ICCAKM)* (pp. 151-156). IEEE.

[7] Babar, M., Tariq, M. U., & Jan, M. A. (2020). Secure and resilient demand side management engine using machine learning for IoT-enabled smart grid. *Sustainable Cities and Society*, *62*, 102370.

[8] Rangel-Martinez, D., Nigam, K. D. P., & Ricardez-Sandoval, L. A. (2021). Machine learning on sustainable energy: A review and outlook on renewable energy systems, catalysis, smart grid and energy storage. *Chemical Engineering Research and Design*, *174*, 414-441.

[9] Thilakarathne, N. N., Kagita, M. K., Lanka, D., & Ahmad, H. (2020). Smart grid: a survey of architectural elements, machine learning and deep learning applications and future directions. *arXiv preprint arXiv:2010.08094*.

[10] Benavides, D. J., Arévalo-Cordero, P., Gonzalez, L. G., Hernández-Callejo, L., Jurado, F., & Aguado, J. A. (2022). Method of monitoring and detection of failures in PV system based on machine learning. *Revista Facultad de Ingeniería Universidad de Antioquia*, (102), 26-43.

[11] Malik, H., Fatema, N., & Iqbal, A. (2021). *Intelligent data-analytics for condition monitoring: smart grid applications*. Academic Press.

[12] Pham, Q. V., Liyanage, M., Deepa, N., VVSS, M., Reddy, S., Maddikunta, P. K. R., ... & Hwang, W. J. (2021). Deep learning for intelligent demand response and smart grids: A comprehensive survey. *arXiv preprint arXiv:2101.08013*.

[13] Ardeshiri, R. R., Balagopal, B., Alsabbagh, A., Ma, C., & Chow, M. Y. (2020, September). Machine learning approaches in battery management systems: State of the art: Remaining useful life and fault detection. In *2020 2nd IEEE International Conference on Industrial Electronics for Sustainable Energy Systems (IESES)* (Vol. 1, pp. 61-66). IEEE.

[14] Haque, N. I., Shahriar, M. H., Dastgir, M. G., Debnath, A., Parvez, I., Sarwat, A., & Rahman, M. A. (2020). Machine learning in generation, detection, and mitigation of cyberattacks in smart grid: A survey. *arXiv preprint arXiv:2010.00661*.'

[15] Sengan, S., Subramaniyaswamy, V., Indragandhi, V., Velayutham, P., & Ravi, L. (2021). Detection of false data cyber-attacks for the assessment of security in smart grid using deep learning. *Computers & Electrical Engineering*, *93*, 107211.

[16] Mostafa, N., Ramadan, H. S. M., & Elfarouk, O. (2022). Renewable energy management in smart grids by using big data analytics and machine learning. *Machine Learning with Applications*, *9*, 100363.

[17] Sayghe, A., Hu, Y., Zografopoulos, I., Liu, X., Dutta, R. G., Jin, Y., & Konstantinou, C. (2020). Survey of machine learning methods for detecting false data injection attacks in power systems. *IET Smart Grid*, *3*(5), 581-595.

[18] Tran, M. Q., Elsisi, M., Mahmoud, K., Liu, M. K., Lehtonen, M., & Darwish, M. M. (2021). Experimental setup for online fault diagnosis of induction machines via promising IoT and machine learning: Towards industry 4.0 empowerment. *IEEE access*, *9*, 115429-115441.

[19] Tiwari, S., Jain, A., Ahmed, N. M. O. S., Alkwai, L. M., Dafhalla, A. K. Y., & Hamad, S. A. S. (2022). Machine learning-based model for prediction of power consumption in smart grid-smart way towards smart city. *Expert Systems*, *39*(5), e12832.

[20] Abu-Rub, O. H., Fard, A. Y., Umar, M. F., Hosseinzadehtaher, M., & Shadmands, M. B. (2021). Towards intelligent power electronics-dominated grid via machine learning techniques. *IEEE Power Electronics Magazine*, *8*(1), 28-38.

[21] Hajji, M., Harkat, M. F., Kouadri, A., Abodayeh, K., Mansouri, M., Nounou, H., & Nounou, M. (2021). Multivariate feature extraction based supervised machine learning for fault detection and diagnosis in photovoltaic systems. *European Journal of Control*, *59*, 313-321.