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OPTIMIZED CONTROLLER BASED VOLTAGE QUALITY ASSESSMENT IN GRID CONNECTED HYBRID MICROGRID

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ABSTRACT

Growing distributed generation based on renewable energy sources pushed for the improvement of power quality. The variable nature of interconnected renewable energy sources such as wind and solar generators, which are reliant on weather and climate change, has an impact on the power quality of micro grids. Power quality assessment involves a number of metrics; including voltage quality, voltage imbalance, sag score, and current score (current THD). Good power quality assessment reduces the energy losses in a power system resulting in high profitability. In this research; voltage quality assessment in hybrid microgrid using a novel krill herd optimization (NKHO) technique is described. Use of NKHO in voltage quality assessment for hybrid microgrids offers a powerful and efficient means of optimizing the control and operation of the microgrid, ensuring its reliability and minimizing its impact on the grid. The proposed technique enables the identification of sensitive buses and the optimal sizing of energy storage systems to mitigate the impact of voltage sags. This research assessed the application of a fractional order proportional, integral and derivative (FOPID) controller for microgrid voltage regulation. The proposed hybrid microgrid is developed using Matlab/Simulink environment.

Keywords: *Distributed Generation, Power Quality, Microgrid, Novel Krill Herd Optimization NKHO, Fractional order PID Controller FOPID.*

1. INTRODUCTION

The use of distributed generation (DG) to generate power has become an increasingly appealing option for both utilities and customers. Transmission expansion, substation capacity upgrades, and DG integration are traditional solutions for power utilities to adjust for the fast rise in energy demand [1]. This focus on reducing greenhouse gas emissions has prompted academics to investigate other non-polluting options. Solar and wind energy systems are the most often utilized renewable energy generating systems [2]. All of these have resulted in the integration of renewable energy resources such as wind and solar, as well as distributed energy resources and energy storage devices such as batteries, flywheels, and ultra-capacitors [3].

The hybrid power system needs an improved control design [4-5] to guarantee its ability to lessen the gap between supply and demand for electricity. The power from renewable sources is unpredictable because it is so dependent on weather, which could led to an imbalance.

When employing a hybrid system over a broad area, it can be difficult to keep frequency and power fluctuations under control [6]. Despite the fact that the FOPID and PID classic are often integrated into hybridizing with other controllers like fuzzy logic, which can give better performance of the system but with complexity in design and implementation, the fractional-order controller is widely considered the best controller for power fluctuations in the hybrid system. Gains for PID controllers are optimized using various optimization methods. Dynamic voltage stability can be enhanced using various optimization algorithms [7].

Inaccurate power distribution and voltage variation may result from poor droop control parameter selection or design [8-9]. This paper makes a significant contribution to the power system by advocating for the adoption of FOPID controller based optimization strategy. To reduce power imbalance between generators and consumers, this work explores an optimal controller to smooth out power and voltage fluctuations in the suggested system. Regulating voltage and power fluctuations on a microgrid necessitates optimizing the gains of PID controllers. To identify a range of PID controller parameters, it was chosen to employ meta-heuristic techniques [10]. Due to the increased usage of non-linear loads and energy-saving devices in reduced voltage networks, power quality (PQ) assessment and research have become crucial for electrical systems. This is a crucial first step toward discovering the current status of electricity quality, locating the dangerous boundary and enacting corrective steps [12]. This paper research goal is to learn more about the current power quality in grid connected hybrid microgrid system and assess how things could be improved.

The variable nature of renewable energy sources due to weather and climate change can have a significant impact on power quality, which in turn affects the reliability and profitability of microgrids.

The research appears to focus on a specific approach to addressing the problem, which involves the use of the NKHO technique for voltage quality assessment and the FOPID controller for microgrid voltage regulation. However, it is possible that the techniques proposed in the research could be adapted and applied to other types of microgrids and renewable energy sources as well.

To achieve the stated objectives of this paper, a description of the microgrid model's features is provided in section 2. Section 3 of this article is confined to the basic block diagram of a hybrid microgrid, which depicts the components and their interactions. Section 4 discusses the impact of novel krill herd optimization in tuning various parameters of FOPID controller. Section 5 includes a comparison of voltage quality at various buses as part of the conclusion.

2. LITERATURE STUDY

Voltage quality assessment is a crucial aspect in the operation and control of grid-connected hybrid microgrids. The assessment involves evaluating the quality of the voltage at various points in the microgrid to ensure that it meets the required standards. Voltage sags, for example, can have significant impacts on the performance of the microgrid and the connected loads, leading to equipment damage, production loss, and reduced reliability.

Several research studies have been conducted on voltage quality assessment in microgrids. For instance, a study by Zhou et al. (2021) proposed an intelligent voltage quality assessment method for a hybrid AC/DC microgrid. The method combines fuzzy clustering and support vector regression to identify and quantify the voltage sags in the microgrid. Another study by Zhang et al. (2020) proposed a voltage quality assessment method based on the kernel extreme learning machine for a renewable energy-based hybrid microgrid. The method evaluates the voltage quality at the point of common coupling (PCC) by analyzing the harmonic distortion and voltage sag. Several previous studies have also highlighted the importance of advanced optimization techniques, such as particle swarm optimization (PSO), genetic algorithms (GA), and artificial neural networks (ANNs), to improve the performance of hybrid microgrids. For example, in a study by Rabbani et al. (2021), the authors proposed a hybrid PSO-ANN approach to optimize the operation of an ESS in a hybrid microgrid, which resulted in improved voltage stability and reduced power losses. However, there are few challenges and gaps that need to be addressed, such as the lack of effective control strategies to mitigate voltage sags and harmonic distortions in hybrid microgrids. Several studies have proposed different control strategies for voltage quality assessment in hybrid microgrids, including model predictive control (MPC) [43], fuzzy logic control (FLC) [44], and intelligent optimization techniques such as particle swarm optimization (PSO) [45], and genetic algorithm (GA) [46]. However, these techniques have limitations in terms of their accuracy, computational complexity, and convergence speed.

Therefore, there is a need to develop an optimized controller-based approach for voltage quality assessment in hybrid microgrids that can effectively mitigate voltage sags and harmonic distortions while reducing the computational complexity and improving the convergence speed. This approach can be achieved by utilizing advanced optimization techniques such as krill herd optimization (KHO) [47], which has shown promising results in optimizing control parameters for voltage quality assessment in hybrid microgrids."Power Quality Improvement in Microgrids: A Comprehensive Review," Ahmad et al. (2021) discuss the importance of power quality in microgrids and the need for advanced control techniques to improve it. They highlight the significance of using advanced control techniques such as the optimized controller-based approach to achieve high power quality in microgrids. In a paper "A Review on Energy Storage System and Control Strategies for Microgrid," Liu et al. (2020) discuss the importance of energy storage systems in microgrids and the need for advanced control strategies to ensure their effective operation. They highlight the significance of using advanced control strategies such as the optimized controller-based approach to ensure the effective operation of energy storage systems in microgrids.

In a paper "Control Strategies for Microgrids: AC comprehensive Survey," Barzegarkhoo and Vahidinasab (2020) discuss the importance of system stability in microgrids and the need for advanced control strategies to ensure it. They highlight the significance of using advanced control strategies such as the optimized controller-based approach to ensure system stability in microgrids. In a paper "A Review of Microgrid Control Strategies," Ghadimi et al. (2019) discuss the different control strategies used in microgrids and the need for advanced control strategies to ensure efficient and effective operation. They highlight the significance of using advanced control strategies such as the optimized controller-based approach to balance the power flow between different sources in microgrids. In a paper "Challenges and Opportunities in Microgrid Implementation: A Review," Dilek and Aydin (2018) discuss the implementation challenges associated with microgrids and the need for advanced control techniques to overcome them. They highlight the significance of using advanced control techniques such as the optimized controller-based approach to address the implementation challenges associated with microgrids.

In summary, by linking the problem statement to specific gaps in the current literature, we can establish the context of the problem and provide a more focused and meaningful research objective.

3. IMPLEMENTED METHODOLOGY

This research is focused on modeling the microgrid using software tools such as MATLAB/Simulink and optimizing the controller through simulation studies. The model includes the hybrid microgrid system, the controller, and the loads. The simulation studies can be used to evaluate the performance of the optimized controller under different operating conditions, such as varying loads, weather conditions, and grid disturbances. Various Power quality issues related to voltage quality are analyzed and ranking is provided to critical buses based on voltage stability index.

4. MICROGRID MODEL

Figure1 depicts the suggested setup which represents multiple energy system with storage.
A Microgrid's stability is compromised by the inconsistent nature of renewable energy sources [11-14]. Solar energy is inherently unpredictable due to its dependence on instantaneous changes in environmental circumstances. This calls for a method of voltage quality assessment to smooth out the hiccups in power variation.

Table 1: Specifications of the Hybrid Microgrid

Chosen system	**Gain(K)**	**Time constant(T)**
System	Chosen value	Chosen value
PV System	$K_{pv} = 1$	$T_{pv} = 1.65$
Wind System	$K_{wg} = 1$	$T_{wg} = 1.3$
Battery System	$K_{BES} = -0.002$	$T_{BES} = 0.1$

Grid connected DG microgrid is depicted as follows: PV system, a DC-DC voltage source converter regulated by maximized power point tracking (MPPT), an inverter, and a modified test distribution system make up the proposed system. Detailed specifications of hybrid microgrid are represented in Table 1.Depending on various operating conditions; the wind turbine generator will produce different amounts of power. Here is the first-order representation of the WTG transfer function:

$$G_{WG}=\frac{G_{WG}}{1+T_{WG}}=\frac{\Delta P_{WG}}{\Delta P_{W}} \qquad (1)$$

To generate voltage and direct current, a photovoltaic system consists of several individual cells interconnected in a certain way. Modeling it with the first-order transfer function is possible. It can be represented as

$$G_{PV=}\frac{G_{PV}}{1+T_{PV}} = \frac{\partial_{PV}}{\emptyset_{PV}} \quad (2)$$

When used with renewable energy sources, energy storage devices can effectively use the system's surplus power and then release the power to loads when there is a shortage. The BESS has a smaller time constant [16]; hence it takes longer to charge and discharge. However, FESS uses a flywheel rotor to store mechanical energy that can later be converted into electricity. Quickly and efficiently, it can provide a lot of power. Modeling it with the first-order transfer function is possible. It can be represented as:

$$G_{BES=}\frac{G_{BES}}{1+T_{BES}} = \frac{\partial_{PBES}}{\alpha_{BES}} \quad (3)$$

$$P_{maingrid} + P_{windsource} + P_{Bes} = \sum P_{Lx_j} \quad (4)$$

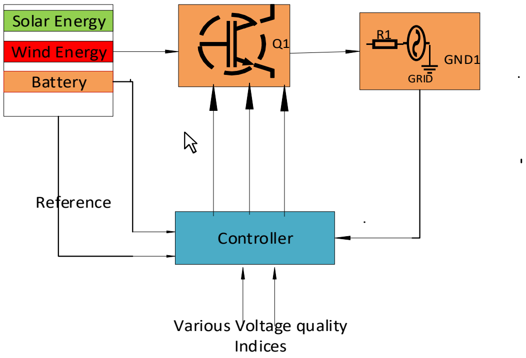

Figure 1: Grid integration of renewable DG System

5. CONTROLLER AND ALGORITHM

The proportional, integral and derivative (PID) controller's objective is to lessen a process variable's dispersion from the desired set point [17-19]. Fractional controllers can improve system performance because they have two additional parameters beyond those of a traditional PID controller: the sequence of fractional integration and the sequence of fractional derivative, these extra parameters allow for more precise modelling and greater freedom in controller design [20, 22]. Optimizing the controller's parameters eliminates voltage and power deviation caused by epistemic uncertainties in generation and load [21].

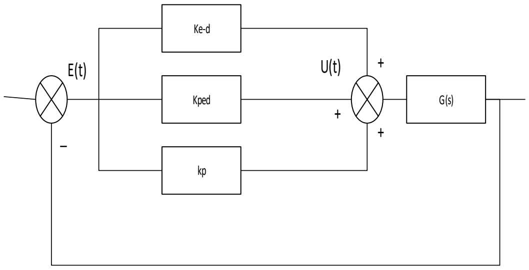

Figure 2: Representation of chosen PID Controller

The novel KHO technique is used to fine-tune the parameters of fractional order PID controllers as represented in Figure 2, to overcome the variations in voltage. The variations possibly due to change from source side as well from load side.

Krill Herd Algorithm: Based on a modelling of the herding behaviour of individual Krill (Euphausia superba) in response to environmental and biological events, the KHO algorithm (Gandomi and Alavi, 2012) is a new swarm intelligent optimization technique [23-26]. The KHO algorithm models the migration of krill, where each member of the herd makes a unique contribution based on its own fitness. The local search for each krill also depends on whether or not the krill in its immediate vicinity have an appealing or repellent influence on each other. Because of their high metabolic rates, krill are able to pinpoint the optimal feeding location, improving worldwide estimates [27]. The KHO method can concurrently explore and take advantage of an optimization problem based on the Hamiltonian and the developmental activity of krill individuals. [28]. The algorithm's reliance on random values means that it benefits more from an adaptive strategy than other bio-inspired optimization methods in terms of convergence speed [11].

Moreover, the KHO method has the unique benefit of requiring a smaller number of parameters to generate krill behaviour for locating the global best [29-30]. The following three events can be used to calculate the temporal position of a single krill: Inducing mobilityN_{ki}, foraging behaviour F_{ki}, and random dispersal in individual krill D_{ki}
A d-dimensional search space KHO algorithm is represented as [32]:

$$\frac{dx_i}{dt} = N_{ki} + F_{ki} + D_{ki} \quad (5)$$

It can be detailed as follows and flowchart shownin Figure 3:

STEP1: (INITIALIZATION) To get started, you must specify settings for Imax (Maximum number of iterations), Nmax (Highest induced speed), Fmax (Highest foraging speed), Dmax (Highest diffusion speed), n (Number of Krill), and X. (position of Krill)

STEP2: (FITNESS EVALUATION) Repeat the steps from 3 ∀ i values upto imax

STEP3: (TERMINATION CRITERIA) calculate the movement for each krill.

STEP4: (END EVALUATION) Processing and display of final result

In N dimensional space Lagrangian model as specified in equation 5, the number and location of the best krill in a given area affect Ni's direction, denoted as i.

In order to determine Ni, the following formula is used:

$$\boldsymbol{N_i^{new}} = \boldsymbol{N^{max}\delta_i} + w_n\, \boldsymbol{N^{old}} \qquad \textbf{(6)}$$

Where $\boldsymbol{N^{max}}$ is the highest generated speed and $\boldsymbol{\delta_i}$ is defined as:

$$\boldsymbol{\delta_i} = \boldsymbol{\delta^{present}} + \boldsymbol{\delta^{target}} \qquad \textbf{(7)}$$

w_n is the inertia weight of the motion induced in the range [0, 1], $\boldsymbol{N^{old}}$is the most recent motion induced, $\boldsymbol{\delta^{present}}$ is the effect provided by neighbours, and $\boldsymbol{\delta^{target}}$ is the effect provided by the top krill in terms of the direction they should move in. The Krill Herd Algorithm process can be presented in the flowchart shown in Figure 6 as bellow. Further details about the Krill Herd optimization technique can be found in the literature as in [12].

The KHO, a swarm-based algorithm inspired by biology, has been shown to be more effective than other Meta heuristic approaches to solving complicated optimization problems [13]. Empirical studies of real-world krill systems informed the values of these coefficients, allowing the KH algorithm to accurately imitate the herding behaviour of krill [12].

The research contribution of this topic lies in its development of an advanced control strategy for voltage quality assessment in hybrid microgrids.

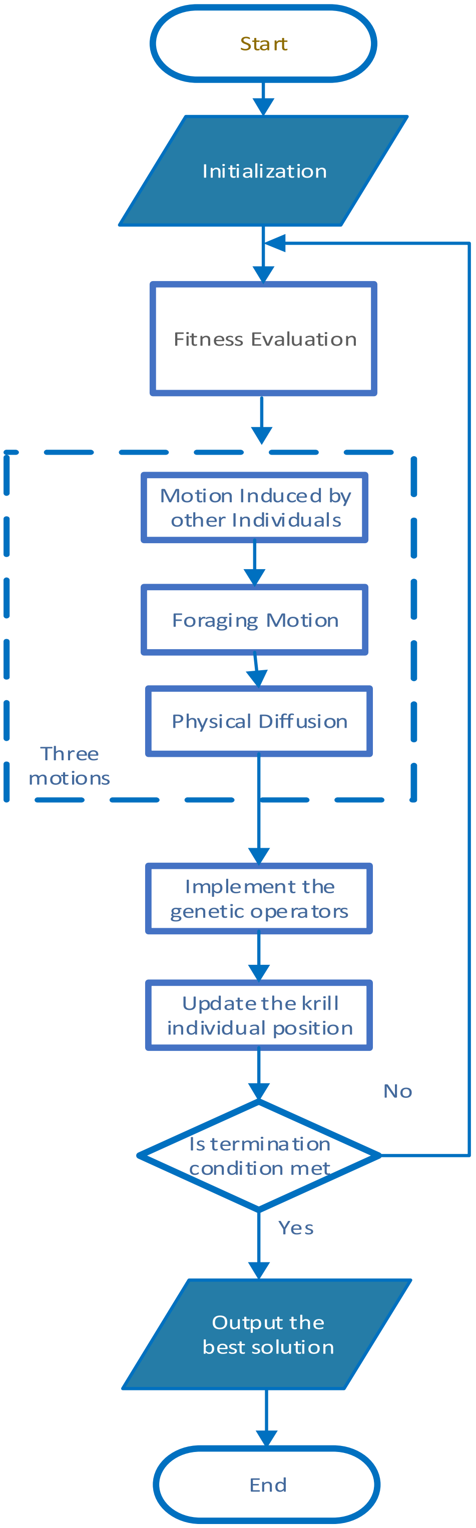

Figure 3: Flow chart showing sequence of algorithm steps

This takes into account the presence of multiple sources and energy storage systems, as well as the need for system stability and efficient power flow management. Compared to other studies presented in the literature, this approach offers several advantages, including : The optimized controller-based approach offers improved accuracy in voltage quality assessment compared to other traditional methods, which may not take into account the complex interactions between multiple sources and energy storage systems.

The importance of optimized controller-based voltage quality assessment in grid-connected hybrid microgrid lies in its ability to offer an advanced control strategy for voltage quality assessment in hybrid microgrids that is more accurate, efficient, and reliable compared to other traditional methods presented in the literature.

6. VARIOUS INDICES OF VOLTAGE QUALITY ASSESSMENT

Both grid-connected and end-user devices may be negatively impacted by PQ problems [14]. Low-quality electricity is produced when there is erratic voltage, an excessive amount of harmonic current in the line, an imbalanced load, a poor power factor (PF), an excessive amount of neutral current, droop, surge, voltage fluctuation, and brief interruptions [15]. In spite of the fact that the proposed method can have additional PQ phenomena added to it with little effort, the focus of this research is on assessment of voltage quality approach.

Various factors affect voltage quality at each and every bus. The following criteria are outlined for determining voltage quality.

4.1. Voltage harmonic distortion: In order to evaluate harmonic performance, the IEEE Std. 519 [16] uses the total voltage harmonic distortion index and it is used at each bus to get a general idea of how well the system is doing overall. Utilizing the Fast Fourier Transform (FFT) analysis tool in MATLAB/Simulink, we have calculated TVHD for up to 100 cycles.

$$\mathbf{TVHD} = \frac{\sqrt{v_2^2+v_3^2+v_4^2 \ldots\ldots\ldots\ldots\, v_n^2}}{v_s} \tag{8}$$

4.2. Voltage sag rank: As one example of a discrete PQ event, voltage sag is triggered when rapid changes in the availability of dispersed RESs disrupt the power flow. Voltage sag is defined as "a reduction in the RMS voltage in the range of 0.1 to 0.9 per unit (pu) throughout an interval of 0.5 cycles to 1 minute," as stated in IEEE Std. 1159 [16]. To assess the severity of voltage sag, sag indices are often calculated using magnitude and duration in relation to threshold limits defined by relevant standards [34]. The voltage sag rank (VSR) is calculated using the magnitudes of the voltages in all three phases, and its formula is given in [17].

$$vsr = \frac{(v_a + v_b + v_c)}{3} \tag{9}$$

4.3. Voltage imbalance: According to IEEE, In order to determine if there is a voltage disparity, one must compare the size of the zero or negative-sequence component to that of the positive-sequence component. In a power system, it is a fluctuation in voltage where the magnitudes or phase angle differences are unequal [33,36]. So, only multi-phase electrical systems have to worry about poor power quality.

Inequitable loads on distribution lines or within a facility is the primary cause of voltage unbalance [38]. If a power system has negative or zero sequence voltages, it's because unbalanced loads are drawing current in the wrong direction.

Maximum voltage divergence from the three-phase average divided by the three-phase average gives a rough estimate of the degree of voltage unbalance.

$$\text{Voltage unbalance} = \frac{\text{Max Deviation from Average Voltage}}{\text{Average Voltage}} \tag{10}$$

4.4 Voltage profile Index: By calculating a voltage performance index (VPI) using the expression [18], we may identify the buses in the system that are particularly voltage-sensitive [39]. Having all buses voltages within their allowable range results in a low VPI value, whereas having them outside that range results in a high VPI value.

$$VPI = \sum_{j=1}^{N} \frac{w_j}{2n} \left(\frac{\Delta v_j init}{\Delta v_j lim} \right)^{2n} \tag{11}$$

Where N is the number of system buses, w_j is the weighing factor of bus j, 2n represents the order of performance index.

$$\Delta v_j init = v_j init - v_j limit \tag{12}$$

$$v_j limit = v_j max \;\forall\; v_j init \geq 0$$

$$\Delta v_j lim = \frac{v_j max - v_j min}{2} \tag{13}$$

7. RESULTS AND DISUSSION

The results of the research on considered standard IEEE test systems are presented here. A customized 14-bus IEEE test system is used in this investigation [39]. The system is equipped with various linear and non-linear loads to study the variation of voltages. There are different factors to consider, including the various source side changes, load variations and other disturbances. By employing FOPID and PID controllers derived from the Krill Herd algorithm, the proposed system is simulated in normal operating conditions. It is determined how one controller stacks up against the other and the findings are displayed.

Assessing the system's robustness entails, the proposed controllers are tweaked with KHO [40]. FOPID based KH is used to simulate the system without the BESS, and DEG, and their effects are evaluated. After that, we compare the outcomes we've gotten. The results of the voltage response for the FOPID and PID parameters are shown primary goal of this correspondence was to examine and enhance the voltage regulation [42].Primary set is to identify critical buses based on the stability indices as shown in Table 2.

Table 2: Identifying and ranking critical buses using voltage stability index

Bus No	Voltages	Voltage stability Index(SVSI)	Ranking
3	**1.005**	**0.8271**	**1**
7	0.9722	0.7421	2
6	0.9643	0.4374	3
8	1.015	0.2707	4
5	1.0063	0.2291	**5**
4	**0.9758**	**0.1488**	6
10	1.0091	0.1367	**7**
1	**0.8955**	**0.1229**	8
9	0.8889	0.0936	9
14	0.9787	0.0803	10
11	0.8995	0.0788	11
12	0.8889	0.0693	**12**
2	0.8889	0.0693	**13**
13	0.8889	0.0693	**14**

These numbers make it clear that in the presence of load and generation unit disturbances, the frequency deviation converges to zero.

By measuring the minimum and maximum voltage at each of the bus in the considered system, condition of the system is assessed as shown in Table 3. Based on minimum and maximum voltage changes identity is given to the buses. As per the possible change in the assessed voltages bus is marked as critical or not critical. With this approach suitable bus locations will be selected for allocating new load for effective utilization of existing system. As per the data shown in Table 3, bus 6 is identified as first critical bus in the order as change in voltage is maximum. Next to that, bus 9 and bus 13 are identified as critical buses. This method of assessment is needed to identify the weak and strong bus locations. Based on this, point of common coupling is decided so that loads allocation and selected DG location in the system is done.

Table 3: Voltage deviation at various buses and critical bus identification

Bus no	Min Change	Max Change	Identity
3	0.2	0.14	NC
4	0.4	0.22	NC
5	0.5	0.3	NC
6	**0.8**	**1.45**	**C**
7	**1**	**0.4**	**NC**
8	0.2	0.15	NC
9	**0.4**	**0.63**	**C**
10	0.5	0.31	NC
11	0.8	0.18	NC
12	1	0.64	NC
13	0.2	0.52	C
14	**0.4**	**0.12**	**NC**

NC- Not Critical C-Critical

These abrupt shifts in generation and consumption must have a significant bearing on power and voltage fluctuations. The controller operation is considered for different cases.

In order to assess the voltage quality, the proposed controller was tuned to represent the most possible changes in the designed microgrid [41-43]. Four different cases are taken into account when eliminating the voltage variations based on the voltage quality indices.

Table 4: Voltage Quality indicators at various buses using NKHO based FOPID

Bus no	**Voltage Harmonic distortion (%)**	**Voltage sag rank**	**Voltage imbalance**
2	3.6	0.14	0.05
4	4.8	0.22	0.1
5	2.32	0.3	1.1
6	6.91	1.45	1.0
7	2.24	**0.4**	**1.06**
8	4.17	0.15	1.1
9	5.25	**0.63**	**1.08**
10	2.12	0.31	-
11	7.07	0.18	0.5
12	8.49	0.64	0.1
13	3.76	0.52	1.04
14	2.33	**0.12**	**0.1**

Case 1: As shown in Figure 4, variation in voltage imbalance is considered based on the loading. At t=107.4ms, voltage imbalance is less with PID controller. As slowly the tuned parameters are optimized, with increase in time as well load changes results the improved performance of FOPID. At t=146.7ms, the optimized controller performance is shown in terms of voltage imbalance as it gets reduced from 4% to 2% which is nearly 50% change.

Case 2: As shown in Figure 5, voltage sag rank is considered based on step by step addition of various DG sources. Initially with all the available capacity of DG,the sag rank is 0.02for PID controller and 0.16 for FOPID controller. Slowly by changing %DG the improvement in sag rank is observed at t=146.7ms. At this instant sag rank redued to very much low value with FOPID Controller.
Case 3: As shown in Figure 6, based on chosen type of load and its behavior, voltage harmonic factor is assessed. With the operation of nonlinear load, the behavior of the system changed with PID and FOPID controller. Increased nonlinear load causes increased harmonic distortion which may affect the complete system. As per the considered FOPID controller, distortion gets reduced compared without optimized controller.

Case 4: As shown in Figure 7, voltage profile index is considered based on various changes in the system either with load or source. Plot shows the improved performance of the FOPID controller compared with PID controller.

When compared to FOPID based other optimized controller, selected Novel KHO based controller reduces the power and voltage fluctuations in the chosen microgrid as shown in Table 4.Additionally, FOPID controllers based on Krill Herd can greatly improve the efficiency of the system. The data reveal that KH-FOPID is superior to KH-PID because of its low- frequency variation and quick transitory variation. Voltage quality is a measure of the deviation of the actual voltage from its ideal value. Voltage quality indicators are used to assess the level of voltage quality at various buses in an electrical power system.

Reactive power is the power that is consumed by inductive and capacitive loads in an electrical power system. Reactive power is necessary to maintain the voltage level within the acceptable range. However, excessive reactive power can lead to voltage instability, voltage sag, voltage swell, and other voltage quality issues. Reactive power is one of the factors that can affect voltage quality. Bus voltages with change in reactive power are shown in Table 5.

Table 5: Voltage Quality indicators at various buses with change in reactive power

Bus No	**% change in load reactive power**	**Voltages**	**Voltage stability Index (SVSI)**	**Ranking**
1	**10%**	**1.0098**	**0.8271**	**1**
9	15%	0.9865	0.7421	2
14	20%	0.9654	0.4354	3
11	30%	0.8925	0.3504	4
12	55%	0.7634	0.2051	**5**
2	**75%**	**0.6758**	**0.1098**	6
13	100%	0.5391	0.0617	**7**

Figures 4-7, display the assessment characteristics of various buses with and without proposed controller categories, and by ranking the buses critical buses are identified.

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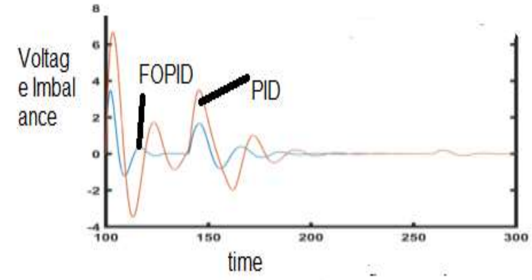

Figure 4: voltage imbalance variation with PID and FOPID

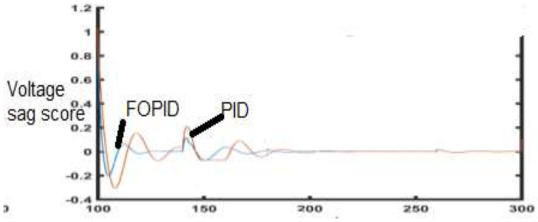

Figure 5: voltage sag score variation with PID and FOPID

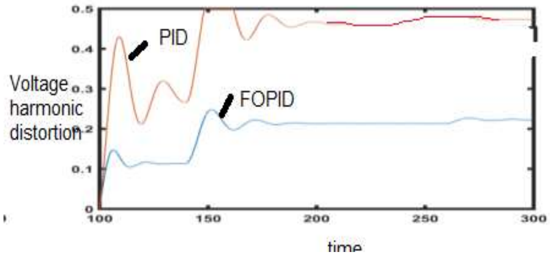

Figure 6: voltage harmonic factor with PID and FOPID

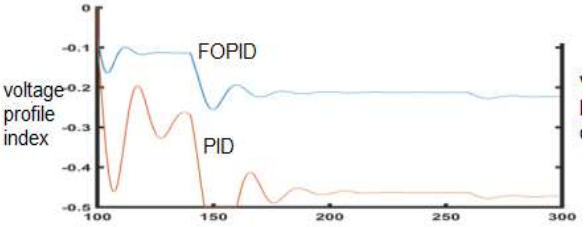

Figure 7: voltage profile index with PID and FOPID

8. CONCLUSION AND FUTURE SCOPE

The chosen novel krill herd based controller proved to be the best in terms of rapid response and improving the system performance by assessing the voltage quality. Identification of voltage quality indices at various buses decides the location to load and utilize the system effectively. Percentage change in load also determines the impact of reactive power and based on this also the voltage quality is assessed. In conclusion, the selected control strategy based optimization technique gives high suitability in microgrid voltage control. In future, selected controller may be used for evaluating or assessing the system performance in terms of other power quality phenomenon.

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