PAPR Reduction in OFDM System Using Metaheuristic Algorithm

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Abstract

The advancement of technology necessitates the development of more sophisticated modulation strategies for wideband digital communication systems. The requirements for high-speed data transmissions can be effectively met by utilizing orthogonal frequency division multiplexing, which is an effective technique. However, a high peak-to-average power ratio (PAPR) is one of the key limits that OFDM systems face, both in terms of their performance and their power efficiency. The evaluation of the PAPR reduction has become a topic of widespread interest in this present decade due to the relevance it holds in the industrial and scientific communities. The purpose of this study is to show the combination of the bat algorithm with the partial transmit sequence scheme as an effective way for reducing PAPR that also eases the burden of computing work. For the purpose of providing a comparative evaluation of the PAPR reduction performance, a number of simulations using various partial transmit sequence schemes have been carried out. The findings of the simulation show that the BA-PTS scheme has the potential to provide superior PAPR reduction performance while simultaneously reducing the computational load.

Keywords: OFDM; Metaheuristic algorithm; PAPR; PTS.

1. Introduction

Orthogonal frequency division multiplexing's popularity in recent decades [1] can be attributed to its many advantages, including its high spectrum efficiency, resilience to fading, robustness to interference, adjustability of sub-carrier rate, simplicity of receivers, and low cost of transmitters. Multiple communication protocols, such as broadcasting [2], asymmetric digital subscriber line services, IEEE 802.16a, IEEE 802.11a/g, and others, rely on OFDM to facilitate high-speed wide band digital transmission. Next-generation digital communication systems, such as WLAN [3], WiMAX, LTE/LTE-A, and so on, may potentially benefit from OFDM. The OFDM protocol is currently widely used in a variety of communication networks. Of particular concern in OFDM systems is the issue of high peak-to-average ratios (PAPRs), which can damage the performance of RF amplifiers and increase the complexity of A/D and D/A conversion. As a result, researchers in the field of digital communications have made PAPR mitigation a primary focus of their attention [4-16].

Techniques such as clipping [5, 6], coding [7, 8], pre-distortion [9-16], and probabilistic scrambling [9-16] can all be found in the literature as ways to reduce PAPR in OFDM systems. The input data are scrambled, and the data sequence with the lowest PAPR is transmitted. This is the basis for probabilistic encoding techniques. Probabilistic scrambling methods include tone reservation,

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selective mapping, tone injection, and partial transmit sequence (PTS) approaches. PTS is the most promising distortion-free method for reducing PAPR, and it has been implemented in a variety of digital communication settings with great success [9, 11].

The starting point of the PTS method is to divide the incoming data into a number of smaller, closely-spaced chunks. A multiple sequence is generated by multiplying each of the blocks by a set of phase weighting variables. The transmission order is determined by selecting the sequence with the smallest PAPR. However, it is a time-consuming and labor-intensive task to search through all of the available phase factors to identify the best phase factor set those results in the lowest PAPR. High-speed data transmissions are impractical in practice [11-16] due to the exponentially increasing complexity of the search operation with the number of sub-blocks. Poor search methods have gained popularity in recent years. used to make determining the optimal phase factor for a task less cumbersome. Some research has suggested using PTS in tandem with less efficient search methods.

Many algorithms are used to reduce PAPR in OFDM [11-17]. It has been proved that swarm intelligence is a good way for handling the challenging challenge of identifying the best answers to problems. This can be difficult because there are often multiple possible solutions.

As an illustration, think about the method of stochastic global optimization. Particle swarm optimization is inspired by social behaviors like fish schooling and bird flocking. The bat algorithm [18] was inspired by the activities of flying and hunting bats. Each particle in particle swarm optimization (PSO) adjusts its position in the search space based on the best position it has achieved so far and the known best-fit particle's position. This is done so that the optimal course of action can be determined. At long last, we're making headway toward the optimal search position. The bat algorithm was inspired by the echolocation patterns of microbats, which can exhibit varying pulse rates of loudness and emission [19, 20].

This paper suggest a PTS strategy combined with a less-than-ideal bat algorithm for efficiently bringing down the PAPR to tractable computing levels. It is proposed to employ a variant of PTS based on interleaved partitioning and QAM sub-blocks in order to lower the PAPR of OFDM signals. In Section 2, we present a theoretical description of the OFDM system. The standard PTS and the bat search optimization technique (BA) for reducing PAPR are dissected and discussed in Sections 3 and 4, respectively. Section 5 describes the simulation findings for the proposed method, and Section 6 wraps up the work.

2. OFDM System Model

Let's imagine that in an OFDM system, $X = [X_0, X_1, \dots\dots X_{N-1}]$ represents an input data sequence that has been modulated by sixteen quadrature amplitude modulation (QAM), where N is the number of sub-carriers. In this example, we'll use the notation "N" to refer to the number of sub-carriers. In light of this, in the domain of continuous time, an OFDM signal denoted by the notation $x = [x_0, x_1, \dots\dots x_{N-1}]$ can be described as

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kn}{N}}, \qquad 0 \leq n \leq N-1 \tag{1}$$

where n is the discrete time index.

In the continuous time domain, the peak-to-average power ratio, also known as the PAPR, of an OFDM signal can be demonstrated with the use of the following formula. One way to express this ratio is to think of it as the peak power divided by the average power.

$$PAPR(x_n) = 10 \log_{10}\left(\frac{\max\{|x_n|^2\}}{E\{|x_n|^2\}}\right) \; dB \tag{2}$$

It is also possible to use the complementary cumulative distribution function, which is more commonly referred to as the CCDF, in order to compare and evaluate the performances of various PAPR reduction approaches.

$$CCDF(N, PAPR_0) = \Pr\{PAPR > PAPR_0\} = 1 - (1 - e^{-PAPR_0})^N \tag{3}$$

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where PAPR0 shows a dedicated value of PAPR.

There is a remarkable similarity between the PAPR features of OFDM signals that operate in discrete time and OFDM signals that operate in continuous time. One technique to attain the optimal performance that is required for PAPR [9-16] is to implement an (L-1)N point IFFT of the symbol sequence with (L-1)N zero padding. It is generally agreed upon that the oversampling factor for the discrete time domain, which is represented by the letter L, should be set at 4.

3. Conventional PTS

Figure 1 depicts the block diagram of an optimized distinctive PTS bat method.

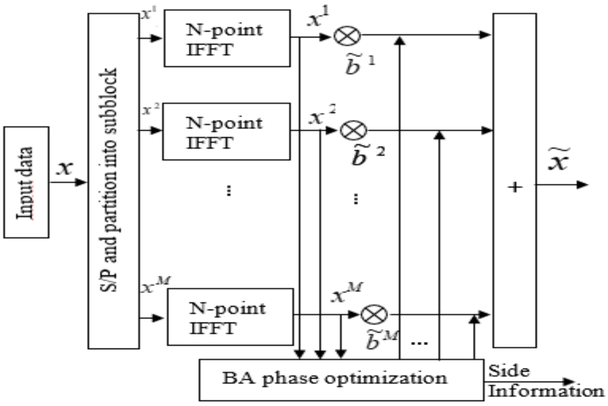

Figure 1: Block diagram of the BA-PTS model

This diagram consists of blocks that comprise adjusted phase rotation vectors is the fundamental idea that drives the PTS scheme's operation as a distortion-free PAPR reduction technique. This principle is central to the PTS scheme. In a normal PTS scheme, the input signal X is typically segmented into M distinct sub-blocks. There is a group of sub-carriers with the same number of members as N within each of these sub-blocks. By guaranteeing that they all have the same number, this ensures that each sub-block has the same number of sub-carriers.

$$X = \sum_{m=1}^{M} X_m \tag{4}$$

where Xm shows the mth sub-block sequence.

Each block has a weighting factor according to the phase given to it. The generated blocks are concatenated after being multiplied by phase rotation vectors. As illustrated in, the applicant sequence x' can then be preserved using IFFT.

$$x' = \sum_{m=1}^{M} b_m . IFFT\{X_m\} = \sum_{m=1}^{M} b_m x_m \tag{5}$$

At last, the applicant sequence that has a PAPR that is the lowest among all of the candidates is the one that is chosen to be sent.

It is essential to have the side information in order for the receiver to effectively obtain the original data stream. In conventional PTS, one can theorize that there are W permitted phase weighting variables. As a result, M represents the number of subblocks, and we are able to collect W^{M-1} applicant sequences. As a result, $\log_2(W^{M-1})$ bits are necessary in order to indicate the side information.

4. Optimization Algorithm

The Bat algorithm (BA) is a stochastic search technique that was first presented by Xin-She Yang [19] in 2010. It was inspired by natural phenomena and is used to solve non-linear as well as linear global optimization problems. It does this by simulating the echolocation used by microbats by employing a number of different pulse rates with variable quantities of loudness and emission. The bat-based algorithm is represented as a flow chart in figure 2, which can be found here.

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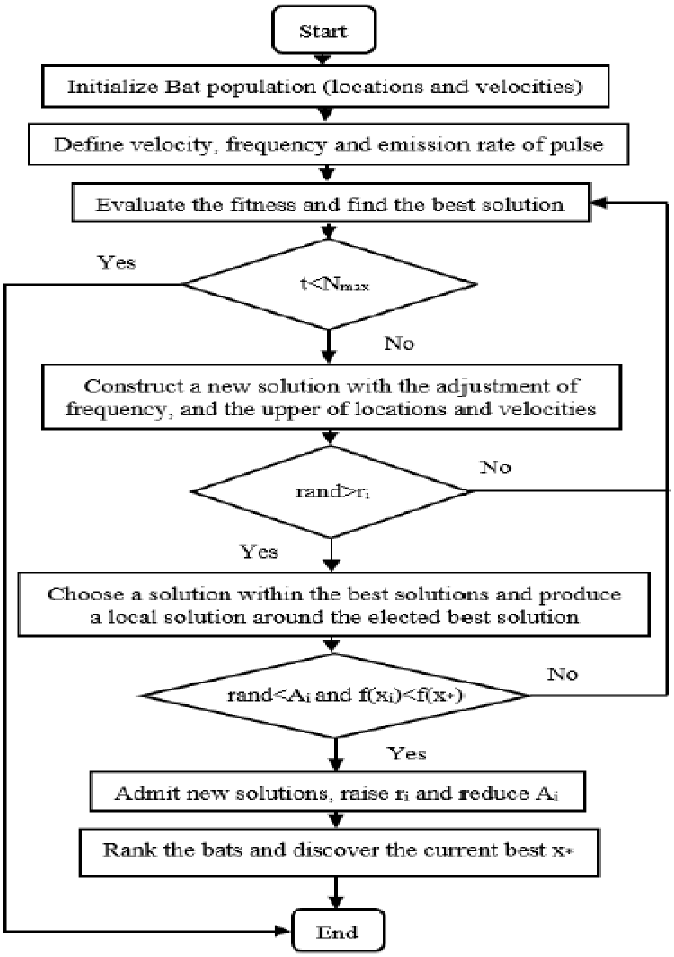

Figure 2: The flowchart of metaheuristic algorithm

The following essential presumptions served as the basis for the development of the bat algorithm, which are in alphabetical order below: In a search space of d dimensions, there are certain straightforward rules that may be used to keep track of the locations (r_i) and velocities (c_i) of bats as the search progresses. A set of new coordinates r_i^t and velocities vit can be given as an expression at a particular time, instance t.

$$f_i = f_{\min+(f_{max}-f_{min})\beta} \tag{6}$$

$$c_i^t = c_i^{t-1} + (r_i^t - r_*)f_i \tag{7}$$

$$r_i^t = r_i^{t-1} + c_i^t \tag{8}$$

5. Simulations

For the purpose of computer simulations, OFDM system with M=16 locks and 16-QAM were created at random. We came to the conclusion that we should use a new number for the generation or iteration G, a new number for the population or particle P, a number for the phase factor W = 2, a number for the number of sub-carries N = 256, a pulse rate R = 0.5, and a loudness A = 0.5. These are the numbers that we chose to use. Table 1 offers an explanation of the major parameters that were used for the simulations. This table is also the location of the table.

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Table 1: The used parameters

Parameter	Value
No. of sub-blocks (M)	16
No. of phase factor (W)	2 ± 1
No. of the iteration (G)	25-50-75
No. of subcarriers (N)	256
No. of the population (P)	10-25-50
Loudness (A)	0.5
Pulse rate (R)	0.5
Modulation method	QAM

The CCDF against PAPR plot of the suggested scheme is represented in Figures 3 and 4, respectively, with the change of the number of populations and the number of iterations.

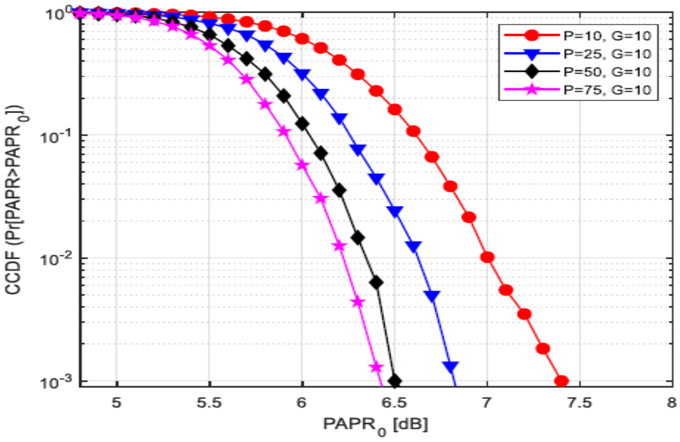

Figure 3: The CCDF versus PAPR0 (dB) for G=10

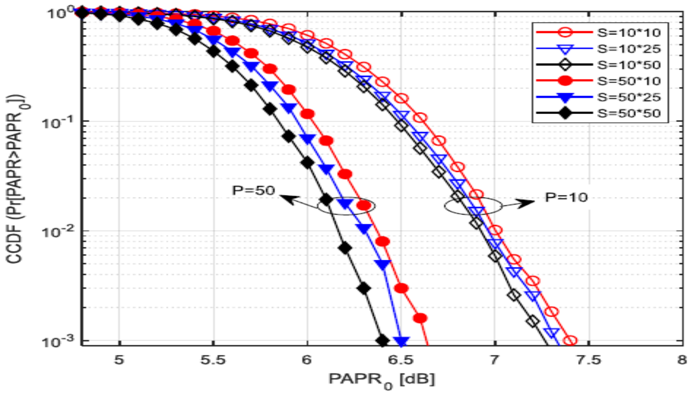

Figure 4: The CCDF versus PAPR0 (dB)
for P=10 and P=50

Figure 3 shows the recommended scheme with the maximum number of populations. Figure 4 shows the maximum number of iterations. The variation is shown in Figure 3 as a function of the number of populations. The variation is shown in Figure 4 as a function of the number of iterations. The parameters ten, twenty-five, and seventy-five for the size of the population; twenty-five, fifty, and seventy-five for the number of iterations; and p set to 10 and fifty, respectively, are the ones that are currently being investigated. Figure 3 presents a plot of the CCDF vs the PAPR for the proposed system, which includes 256 subcarriers. This plot is given in the context of the proposed scheme. That fact should not come as a surprise at all.

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When there are more people living in a certain area, the population-adjusted rate of poverty (PAPR) is shown to fall by a substantial amount, as is evident. The PAPR values are as follows for a population density of 103: for 10 people, it is 7.4 decibels; for 25 people, it is 6.82 dB; for 50 people, it is 6.51 decibels; and for 75 people, it is 6.42 decibels. When compared to the conventional PTS, the PAPR was reduced by approximately 3.55 decibels for 10 population, 4.13 decibels was achieved for 25 population, 4.44 decibels was reached for 50 population, and 4.53 decibels was achieved for 75 population. All of these results are in comparison to 75 population.

A presentation of the outcomes of the simulation can be seen in Figure 4, which can be found in this location if you want to look there. The usage of population thresholds ranging from 10 to 50 people has resulted in the development of a method, which was accomplished by applying a number of iterations. The starting points for the iterations are 10, 25, and 50. These are the numbers that were selected to be the winners. The number of sub-blocks, which is marked by the letter M, is equal to 16, and the number of sub-carriers, which is designated by the letter N, is equal to 256 in this particular implementation.

This conclusion is backed by the fact that it has been observed that raising the total number of iterations leads to a considerable decrease in PAPR. This finding lends credence to the assertion that increasing the total number of iterations reduces PAPR. When P is set to 50, the PAPR values are 6.62 dB, 6.5 dB, and 6.42 dB, respectively, for iterations of 10, 25, and 50. These values are in accordance with the previous statement. When P is equal to 10, the respective values of PAPR are 7.42 decibels, 7.3 decibels, and 7.28 decibels.

The findings of a comparison between the performance of the suggested method and that of a number of alternative PTS-based PAPR reduction strategies are presented in Figure 5.

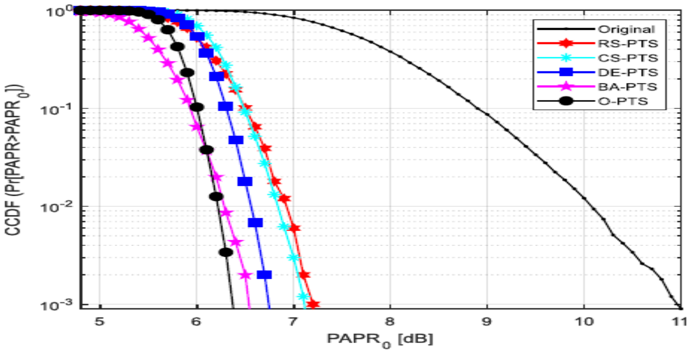

Figure 5: The CCDF versus PAPR0 (dB) of optimum
PTS, BA-PTS, DE-PTS, CS-PTS, RS-PTS and the original

These strategies all aim to lower PAPR levels. The terms "optimum," "random search," "differential evolution," and "cuckoo search" all refer to distinct search strategies. In a situation where CCDF is equal to 10-3, the PAPR of the original signal is 10.95 dB, whereas the PAPR of the random search (RS) signal is only 7.2 dB. The following is a table that provides the PAPR values for the suggested system, the cuckoo search (CS), the differential evolution (DE), the Optimum-PTS (O-PTS), and the suboptimal techniques: 6.75 dB for the cuckoo search (CS), 6.37 dB for the optimum-PTS (O-PTS), and 7.1 dB for the differential equation (DE). The PAPR of the BA-PTS is reduced by 21, 0.56, and 0.66 decibels, respectively, when compared to the DE-PTS, the CS-PTS, and the RS-PTS, respectively.

This is true even if the level of complexity of the search is maintained at the same level. According to the results of the comparison, it is possible to draw the conclusion that the PAPR reduction made available by the BA-PTS in an OFDM system is superior to the reductions made available by the RS-PTS, the CS-PTS, and the DE-PTS. This is the conclusion that can be drawn from the findings of the comparison.

Some examples of these schemes are optimal, particle swarm optimization, and harmony search. When CCDF equals 103, the PAPR of the original system is 10.95 decibels, but the PAPR values for and the suboptimal alternatives are 7.45 decibels for the PSO-PTS, 7.27 decibels for the HS-PTS, and 6.54 decibels for the suggested system respectively. These PAPR readings are less than the value of

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10.95 dB that was recorded for the initial system. In spite of the fact that the BA-PTS has the same amount of search complexity as the PSO-PTS and the HS-PTS, the PAPR of the BA-PTS is reduced by 0.91 dB when compared to the PAPR of the PSO-PTS and by 0.73 dB when compared to the PAPR of the HS-PTS. Based on the comparison, it is clear that the BA-PTS generates noticeably superior outcomes. The PAPR for the OFDM system came in with a substantially lower number when compared to both HS-PTS and PSO-PTS. Compare and contrast these results.

6. Conclusion

In this research, we deal with the PAPR problem by presenting a PTS that is based on the bat method in the OFDM system. This helps to reduce the complexity. Simulations with the CCDF are carried out in order to evaluate the effectiveness of the proposed BA-PTS method in lowering PAPR. Comparisons are made between the PAPR reduction performance and the computational load of the original PTS, the Optimum-PTS, the RS-PTS, the CS-PTS, the DE-PTS, the PSO-PTS, and the HS-PTS. It has been demonstrated that the BA-PTS scheme offers higher PAPR reduction performance with a lower overall computational burden compared to other PTS schemes, such as RS-PTS, CS-PTS, DE-PTS, HS-PTS, and PSO-PTS.

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References

[1] Yang S, Yang W, Cai Y, Wei L, An energy efficient PTS scheme for PAPR reduction in OFDM relay systems. in ChinaCom2015: Shanghai, China, 858-863.

[2] Patidar M K, Mishra A, Saxena R, Partial approximate gradient constellation for PAPR reduction in OFDM signals. International Journal of systems, Control and Communications, 7(1), 83-96, 2016.

[3] Joshi A, Saini D S, Peak-to-average power ratio reduction of OFDM signals using improved PTS scheme with low computational complexity. WSEAS Transactions on Communications, 12(12), 630-640, 2013.

[4] Eid Marwa M, Fawaz Alassery, Abdelhameed Ibrahim, and Mohamed Saber, Metaheuristic optimization algorithm for signals classification of electroencephalography channels. Computers, Materials & Continua, 71(3), 4627-4641, 2022.

[5] M. Saber, Efficient phase recovery system, Indonesian Journal of Electrical Engineering and Computer Science (lJEECS), 5(1), 123-129, 2017.

[6] Jones A E, Wilkinson TA, Barton S K, Block coding scheme for reduction of peak to mean envelope power ratio of multicarrier transmission scheme. Electron Lett, 30(25), 2098–2099, 1994.

[7] Sharma C, Tomar S K, Gupta A K, PAPR reduction in OFDM system using adaptive coding technique with pre distortion method. WSEAS Transactions Communications, 10(9), 255-262, 2011.

[8] Mohamed Saber, A novel design and Implementation of FBMC transceiver for low power applications, Indonesian Journal of Electrical Engineering and Informatics (IJEEI), 8(1), 83-93, 2020.

[9] Jie Y, Lei C, Quan L, De C, A modified selected mapping technique to reduce the peak-to-average power ratio of OFDM signal. IEEE Transactions Consum Electr, 53(3), 846-851, 2007.

[10] Alharbi AH et al., Diagnosis of Monkeypox Disease Using Transfer Learning and Binary Advanced Dipper Throated Optimization Algorithm. Biomimetics, 8(3),313, 2023.

[11] Cimini L J, Sollenberger N R, Peak-to-average power ratio reduction of an OFDM signal using partial transmits sequences. IEEE Commun Lett, 4(3), 86-88, 2000.

[12] Tokur Bozkurt Y, Taspinar N, PAPR reduction in OFDM systems using partial transmit sequence with Cuckoo search optimization algorithm. International Journal of Intelligent Systems and Applications in Engineering, 4(1), 260-263, 2016.

[13] Hung H L, Huang Y, Peak-to-average power ratio reduction in orthogonal frequency division multiplexing system using differential evolution-based partial transmit sequences scheme. Commun IET, 6(11), 1483-1488, 2012.

[14] Taspinar N, Kalinli A, Yildirim M, Partial transmit sequences for PAPR reduction using parallel tabu search algorithm in OFDM systems. IEEE Commun Lett, 15(9), 974-976, 2011.

Doi: https://doi.org/10.54216/JAIM.040203
Received: November 09, 2022 Revised: April 26, 2023 Accepted: July 02, 2023

[15] Taspinar N., Karaboga D., Yildirim M., Akay B, PAPR reduction using artificial bee colony algorithm in OFDM systems. Turk J Elec Eng & Comp Sci, 19(1), 47-58, 2011.

[16] Chaieb H, and Sakly A, Review and comparison BAT and PSO MPPT's based algorithms for photovoltaic system. WSEAS Trans on Power Systems, 13, 108-117, 2018.

[17] Yang X S, A new metaheuristic bat-inspired algorithm- Inspired Algorithm, Nature Inspired Cooperative Strategies for Optimization, Springer, 284, 65-74, 2010.

[18] M. M. E. Bahy, S. A. Ward, M. Badawi and R. Morsi, "Particle-initiated negative corona in co-axial cylindrical configuration. Annual Report Conference on Electrical Insulation and Dielectric Phenomena, Montreal, QC, Canada, 343-348, 2012.

[19] E. M. Shaalan, S. M. Ghania and S. A. Ward, Analysis of electric field inside HV substations using charge simulation method in three dimensional. Annual Report Conference on Electrical Insulation and Dielectic Phenomena, West Lafayette, IN, USA,1-5, 2010.

[20] Mohamed A. Abouelatta, et al. , Measurement and assessment of corona current density for HVDC bundle conductors by FDM integrated with full multigrid technique. Electric Power Systems Research, 199, 2021.

Doi: https://doi.org/10.54216/JAIM.040203
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