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ORIGINAL RESEARCH

Robust Smart Grid Monitoring Network Based on Direct Sequence Spread Spectrum Intelligence

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Abstract
The ascendance of the smart grid concept has provided high hopes of developing an intelligent network that is capable of being a self-healing grid and ability to overcome the interruption problems. We developed a MATLAB-based system to examine the effect of jamming for smart grid applications in improving the reliability of the smart grids via MCS approach to model physical CTSF 34- node. The objective is to measure jamming effects on the dependability indices, BER through direct spread spectrum. This paper also analyses the effects of varying the jammer bandwidth for the CTSF node smart feeder (mode 1) and its Markov model (mode 2) with DSSS simulated BER results in less than 0.5 approximately and robust for random variation in jamming signal.

Keywords Monte carlo simulation · Direct sequence spread spectrum · Compressive test smart feeder · Intelligent electronic devices · Stochastic model · Time to repair · Time to fail

Introduction

The showing of physical layer of smart grid advances is a turning point in the affectability and quantitative probabilistic examination. Among a considerable amount, lot of its incredible ideals is its ground-breaking capacity to precisely assess the unwavering quality of the electrical grid. In this way, the requirement for feasibility assessment of electrical appliances and connections to conduct had being stressed over the latest decade. PDSoDSSI is being chosen as a procedure for simulating the entire irregular and might able to partitioned into three fundamental categories; mode-0, mode-1 and mode-2 methods [1]. The successively demonstrated CTSF 34-node test framework utilizing MPLOSG based on spread spectrum with spectrum sensing to simulate the system operation with jitter and noise on AWGN channel and broadened time latency, where a proposed framework is compared with customary QPSK modulation and existing. It provides with a distribution information via spread spectrum with spectrum sensing within wide applications for systems like load point indices, and also for system indices [2, 3]. So, a developing information aggregated at all levels of the smart grid empowers researchers and power system administrators to propel the power system to work in a more secure, monetary and economical way [4].

Machine Learning and Data Investigation for Smart Grid

New information sources, for example, PMUs, micro-PMUs, intelligent electronic devices (IEDs) and smart meters, are getting to be standard in the existing power grids. As per a report from National Sustainable power source Research centre (NREL) [5, 6], a synchronized PMU ascertains and stores 30–60 data point per second. A system with 5 PMUs can create a 13.8 MB report each hour. Private shrewd meters may create information at a much lower rate; however, smart meters are considerably more typical accordingly are producing information of practically identical size. As indicated by the Edison

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Establishment [2], with over 42% of the Indian family units having a smart meter, in excess of 57 million smart meters have been introduced in India by 2017, which day by day create 1.2 billion data points [3].

State-of-the-Art Physical Modelling for IEEE 34-Node Test

System with Dependability Parameters

Different research papers [2, 3, 7–12] demonstrate the smart grid as a lining system. In Ref. [1], the smart grid time and length are resolved in a deterministic way by some arcade signals and a settled separation conveyance. In Ref. [6], a $M/M/N_{\max}$ line is presented, where the SG arrives as a Poisson procedure with an exponentially appropriated charging time, and $N_{\max}$ is the aggregate charging limit. Reference [9] utilizes a $M/M/\infty$ line to catch the way that private smart grid is a self-benefit framework. Both Refs. [4, 13] accept the smart grid entry rate is not identified with the quantity of SGs that are as of now in charging mode. The $M/M/s$ models in Refs. [14] depend on the suspicion that the entry procedure of a smart grid occasion is a homogeneous Poisson process with a steady rate, and that the charging span is exponentially circulated. In spite of the fact that we can infer the long-run normal properties of the previously mentioned models logically, the greater part of these models depends on some unrealistic presumptions without approval.

On account of the generally introduced smart meters and corresponding infrastructure, investigators and practicalities have possessed the capacity to access the vitality utilization configurations of customers with incredible determination and huge measure. In this section, we recommend innovative information determined way just before deal with build up a substantial model for private smart grid request by applying enormous information investigation on estimations specifically gathered from smart grid decks. Smart Grid practices are identified with factors such as area, client work, or suave the cost of gas, the canny meter perusing alone can be a decent pointer, which abridges all these communal factors. The recommended model empowers us to catch the non-homogeneity and periodicity of the smart grid demand. In addition, we appraise the smart grid term with an experimental *pdf* created from the genuine canny meter data.

The recommended new model does not demand any of the pre-suspicion specified previously. Moreover, the model can be additionally utilized by electric utilities for upgraded projection of SG plea and organization of cutting edge dexterity solicitations as a feature of interest reaction and grid services obtaining [12].

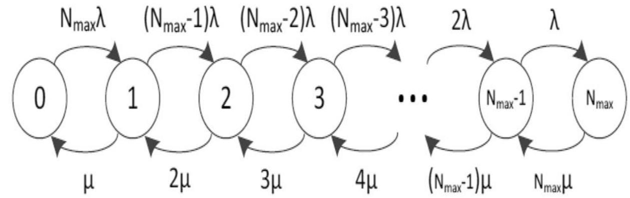

Fig. 1 Transition diagram of the system with finite calling population

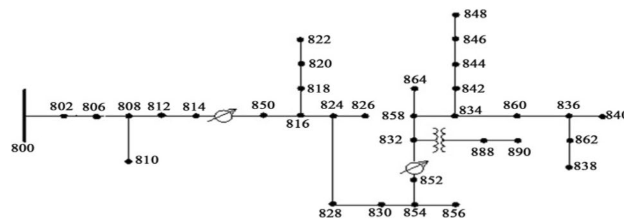

Fig. 2 The IEEE CTSF 34 Node Test Feeder

Stochastic Models of Smart Grid Demand

Data Perception

The key preferred standpoint of the data compelled SG model is that the model is supported by candid canny meter estimations. The smart meter data not just furnish us with the learning of private smart meters designs, but also show a vibrant role in model approval.

$1/M2/\infty/N_{\max}$ Queue with Limited Calling Population

In the first place, the $M1/M2/\infty/N_{\max}$ demonstrates that the entry rate of new smart grid events continues as before regardless of what number of SGs is as of now in the indicting state. Still, this is not valid as extended as the quantity of SGs is limited. In a network with a limited number of SGs, the potential fresh introduction rate of new smart grid events diminishes as the number of indicting SGs increments. In other words, let λi be the landing rate when there are i SGs in the system, for any two integers $\{a, 0 \le a < b \le N_{\max}\}$, we have $\lambda_a > \lambda_b$.

To archetypal limited number of private SGs, we present the limited calling inhabitants model [6] for the $M1/M2/\infty/N_{\max}$ queue. Expect every SG arrives autonomously as per a Poisson procedure with rate λ, at that point $\lambda_i = (N_{\max} - i)\lambda$ (Figs. 1, 2).

Another favourable position of embracing the limited calling inhabitants system is creating the model versatile what is more, more vigorous. Under the limited calling inhabitants' methodology, rather than assessing the conduct of all N_{max} SGs, we evaluate the conduct of every SG. As long as the assumption that all SGs conduct autonomously holds, transform the model with a subjective number of SGs.—8-6-4-202468-0.500.51Lag (days) Autocorrelation Period: 1

A General $M1/G/\infty/N_{max}$ Show

Another supposition made by the $M1/M2/\infty/N_{max}$ shows that the indicting span of SGs is exponentially disseminated. We will demonstrate this assumption is not legitimate via memory less property of the exponential dispersal [15]. Accept a SG begins alleging at time $t=0$. Let $(t>T)$ remain for the probability that the alleging length t is more noteworthy than T hours, and $(t>T+S|t>S)$ the restrictive probability of the alleging more than $T+S$ hours given S long periods of charging. As per the memory less property of the exponential dispersal, $(t>T)=(t>T+S|t>S)$. This repudiates the regular learning of smart grid conduct, since the battery limit of SGs is constrained.

To enhance the model of the smart grid length, we receive an experimental alleging time circulation assessed from genuine smart grid estimations.

Model Estimation and Approval

As specified in the past segment, the information-driven model created in this part depends on the authentic information of 37 private SGs for finite time. Half of data are utilized for model preparing and bound approximation (preparing data collection), and the other half of data model (approval data collection) [7].

Model Parameter Estimation

We try to show the private smart grid conduct through a $Mt/G/\infty/N_{max}$ line with limited calling inhabitants, where Mt remains for the intermittent non-homogeneous entry rate; G remains for the experimental circulation of smart grid span; ∞ implies the alleging system is a self-driven system with no holding up time; and N_{max} is the quantity of SGs in the network.

Proposed Stochastic Model

The objective of this work is to demonstrate the physical layer based on spread spectrum with range detecting for smart grids for the system based on 34 test node required by CTSF, stated below (Fig. 3) for determining failure reliability o and restoration process for two-state models.

Especially, on behalf ideal situations of ARs over the feeders, we are going to consider the effect over automatic recloses (ARs) and in addition to that circulated generators

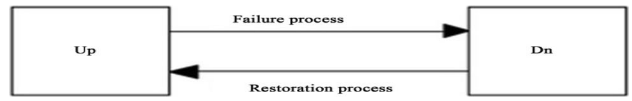

Fig. 3 Showing two-state model of a component

over an system, as proposed Markov model just support over an formation of history that is an artificial one for a recreation time for every segments and that was described under work year 2000 [16], so we are working towards the outputs which we had obtained from stochastic model based on proposed model and the previous obtained results based on different approaches [5].

The system data on which we are working are mainly taken from Ref. [17], which was further utilized by many authors for examination purpose for their reliability [5]. So, the load point records and system list are wholly assessed by distribution system dependability, which have been considered as the normal failure rate represented by (is), normal blackout time is represented by (r) and the normal yearly unapproachability (u).

Proposed stochastic model randomly sample these up and down stated for every component within feeder which supports to produce a history of task along with failure which comes under simulated sequence. These aid in delivering a general decision about the system conduct as a rule, and to distinguish the segment that is inclined to out-age specifically.

The technique considered in the coding is the time-sequential proposed stochastic model, which enhances the modelling of the system perceiving a sequential request over an occurrence happened based over the system observed through the simulation time. Using arbitrary number, artificial history is being created which supports with delivering an unvarying irregular numbers (in the vicinity of 0 and 1), so the objective of providing a succession work repairing cycle for it is provided with every segments [9].

Figure 3 states eminent two-state Markov model which is being used for re-enacted of CTSF test system for all the non-source portions in the feeder. As the technique is exceptionally irregular in nature, we do not have any idea about when the frame is to be aligned, where to aligned and which portion to be aligned for the framework and which one would flop within priority wise with the manner in which there will be a lead that would be one of a kind in connection to one section to another, including the sort and number of disappointments and furthermore the time between a disappointment and revamping of a fragment. This reality is added to the goals of proposed stochastic model as a pivotal mechanical assembly to demonstrate these certifiable principles of lead in a re-enacted time for making ordinary unwavering quality characteristics for a framework while considering genuine arrangement variations, which might be the consolidation over smart grid advancements within its foundation. The Markov model has been divided into two states; first one is up which is for the sections working conditions, second one is down which explains failing state. The up state is being referred to as TTF (time-to-fail), while the down state is being referred to as TTR (time-to-repair/replace). TTR and TTF both are unpredictable in nature. So the technique used from up to down is meant as the disappointment procedure for a section because of probability event that would expel it from undertaking. MCS self-assertively test over here and there is being stated for each segment over the feeder which makes a mimicked grouping towards the part's history of task and disappointment. This may help towards making a general choice about the system behaviour as a rule, and to recognize the portion that is inclined to power outages particularly.

MCS Simulation Process for Proposed Stochastic Model for Proposed Smart Grid

References [4, 5, 10] gave direction on the MCS procedure that was used in this work. The procedure can be basically narrated as:

1. Using arbitrary number generator, initially going to create an arbitrary value and an equal probability values are assigned in between (0,1).
2. Decide whether segment in the framework having the least TTF.
3. Convert the created values into TTF, TTR for every part in the system. Then, decide the blackout span for each load point indices which is not successful.
4. Now, produce fresh arbitrary number for the failed segment and convert them into new TTF and compare the value. If the require simulation time is less than a year, then step back to step 2, else step forward to stage 7.
5. Now, the number as well as duration of failure has been computed for each load point per year and then average has been taken.
6. If simulation time > total simulation years, then go to stage 2. Otherwise, record results and end.

$$\mathrm{TTF}_i = -\frac{\ln(U_i)}{\lambda_i} \times 8760\,\text{hours}$$

$$\mathrm{TTR}_i = -\ln(U_i) \times \mathrm{MTTR}_i\,\text{hours}$$

Table 1 BER and total error rate performance of proposed PLoSSI system

Sr No.	Var level	Mode 0 PLOSSISG BER	Mode 1 PLOSSISG BER	Mode 2 PLOSSISG BER
1	0.4	0.5461	0.5547	0.5547
2	0.8	0.5469	0.5547	0.5547
3	1.2	0.5492	0.5547	0.5547
4	1.6	0.5485	0.5547	0.5547
5	2	0.5485	0.5547	0.5547
6	2.4	0.5485	0.5547	0.5547
7	2.8	0.5485	0.5547	0.5547
8	3.2	0.5485	0.5547	0.5547
9	3.6	0.5477	0.5547	0.5547
10	4	0.5477	0.5547	0.5547

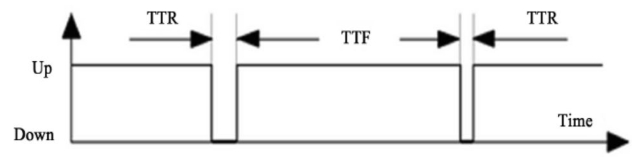

Fig. 4 The operating/failure time of a component

Modelling the Test System of Smart Grid Technologies

Consideration of One Automatic Reclose in the Feeder

The outcomes show that MATLAB code for the test system is given in Table 1. Smart grid utilization advances over the unwavering quality is somewhat. The impact of the smart grid application Monte Carlo (the auto-reclose for this circumstance) shows the appropriation feeder and is said something perspective towards the outcomes (of utilizing the successive Monte Carlo against the customary (main) plan of the test structure in Fig. 4.

The adjustment towards the dependability records is an aftereffect towards the way that the auto-recloser may able to have the excellence of withdrawing the error and restores towards the support of the sound portion over the feeder, which is then added towards to the fast empathy towards the faulted region, which moderates the repair hours. These two factors mostly renovate the consistency indices overall and save maximum energy, money and push towards the utilities. Figure 4 states the line diagram for the decline in undistributed energy that has been recorded as per each option under consideration. By building a connection among the results obtained after the informative procedure and among the savage power over the examination done by the authors in [5], so ones were obtained using MATLAB code named as MCS, we found an adjacent effect towards the foundation over the automatic reclosed within each option obtained at EUE, which its idea was obtained on a very basic level from the National research facility of Lawrence Berkeley, where there was only a 4.3% differentiation among the rates of change in the two methods. So, the two procedures are capable and give comparable outcomes with respect to surveying the dependability of the given framework subsequent to applying the smart grid applications obtained as result.

Direct Sequence Spread Spectrum (DSSS) System Model

DSSS tweak can be portrayed as a strategy for transmission; for example, the information obtains an independent of the information arranged using arrangement of coding. As we require to transmit an advance information, we have to inhabit the thought spreading over a transfer speed expansion far past. For consideration, a prerequisite way towards transmitting data by using an information Rd = 256 Kbits/s having a range transmission capacity of *W*ss = 256 MHz has a spreading component of 105 as the proportion between the BWsp and the BWs.

The epic characteristics and motivation driving DSSS tweak is that gives impedance concealment, vitality thickness decline or time postpone estimation [18]. The interference suppression can be combinations of the presence of users with the intention of disrupt the communication or clients that independently share a common channel without an external synchronization.

Self-obstruction was lessened, which is caused by multiway and postponed signals.

Spread range gives low probable of block attempt and low likelihood of abuse. The mistake is conversely corresponding to the spread range flag transfer speed.

A streamlined pattern model of DSSS system is depicted in Fig. 5 [10]. The information hail $X(t)$ addresses situated opposite side of the heartbeat stream within qualities ± 1, within a given information rate at which it is tweaked via duplicating with bearer flag $\sqrt{P}\cos\omega ot$.

The resultant thing is a parallel stage move keying (BPSK) hail $S\,x(t) = x(t)\,P\cos\omega ot$, as we see BPSK hail is expanded by a scattering succession $C(t)$ within a required higher information rate called chip rate. Then, the effect of a data transfer capacity advancement has been given by the convolution of $S\,x(t)$ and also $c(t)$ in recurrence area. Along these lines, if the banner $S\,x(t)$ is thin band, at that point the subsequent item $Sx(t)\,c(t)$ is satisfactorily spread a transfer speed generally proportional to the spreading signal.

At the receiver, as shown in Fig. 6 [5], the original signal is recovered from the synchronized spread spectrum signal where the parameter ˆTd is a estimated delay introduced by propogation time of transceiver. The flag $r(t)$ is been considered without obstruction with steady framework within gain A and a discretionary stage ϕ within the range of $(0, 2\pi)$. For spreading the banner $c(t) = \pm 1$, at that point grouped over the item $c(t - \text{Td})\,c(t - \hat{\ }\text{Td}) = 1$ for perfect synchronization with Td = ˆTd. For a coordinated flag, correlation work yield is the dispread tweaked flag (while we consider an irregular stage and defer Td), subsequently the flag is separated with the termination objective to expel high recurrence segments and conventional demodulator is being used as demodulator. Any undesirable flag would be spread by the data transfer capacity. The favourable position as far as obstruction dismissal is given by the way that the incoming signal is increased by over one time within the recipient though the transmitted flag is duplicated over twice times with the termination objective to recuperate a decent gauge of the first flag $x(t)$.

For the goal of covering the coveted flag by a band restricted white Gaussian clamour of high power, it has been compromised with commotion sticking. The essential favourable position of clamour sticking is that it does not need more point by point data about the correspondence past its spread transmission capacity [1]. In this methodology, the sticking transporter flag is tweaked with arbitrary clamour. Contingent upon the transfer speed accessible commotion sticking method fuses [12].

Clamour sticking relates to the correspondence framework limit channel (C), which consist the most extreme rate

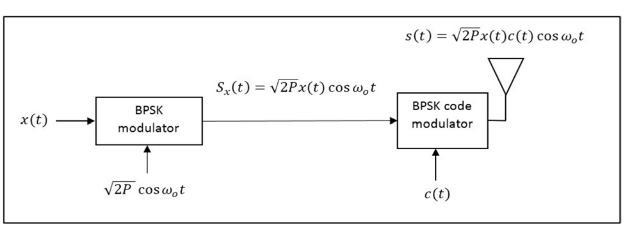

Fig. 5 DSSS BPSK modulator [5]

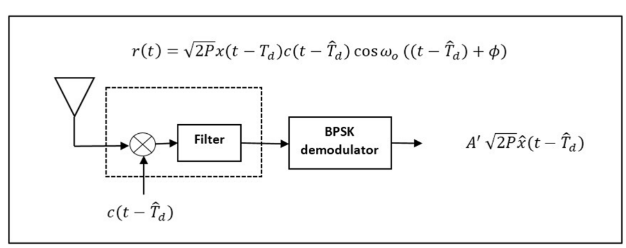

Fig. 6 DSSS BPSK demodulator [5]

through which the information can able to be transmitted. It deliberates a band-confined channel with background noise within flag control constrictions spoken to as:

$$C = B\log_2\left(1 + \frac{S}{N_oB}\right)$$

where C states channel capacity in bits/; B states channel bandwidth in Hz; S states average received signal power in the channel bandwidth in Watts; N_oB states average noise power in Watts, noise spectral density and bandwidth product; S/N_oB states signal-to-noise ratio.

In terms of interfering, if an average noise power increments by adding intended interference, then the channel capacity is affected by SNR reduction in the presence of noise [11].

System Block Diagram of Physical Layer Based on Spectrum Sensing Intelligence (PLoSSI) for Smart Grid

Figure 7.

Direct Spread Spectrum Jamming

Need for simulation and analysis of direct sequence spread signal with single tone jamming function through QPSK modulation (may extend for double tone). Result should display BER plot of DSSS over QPSK modulation for different jamming amplitudes.

Here, we can introduce two modes as Mode-0 to find and plot the BER plot and Mode-1 to get the different plots

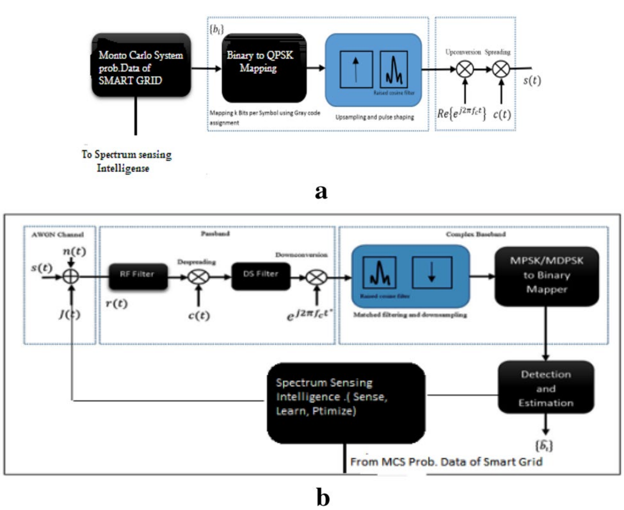

Fig. 7 Overall power distribution system based on DSSS Intelligence. **a** Block diagram of transmitter, **b** Block diagram of receiver

explaining input signal and separated signal for I channel and Q channel for QPSK modulation, PN sequencing and spreading. This file may displays plots for the QPSK modulation, AWGN with standard noise and single tone jamming noise, QPSK demodulation at receiver and despread signal, etc.

Direct Spread Spectrum (DSS)

This file may spread the data by the PRN sequence generated previously, and plots are needed to be scaled by the data rate and impact of high ratio between the chip rate and the data rate.

Despread Spectrum (de_SS)

This file will multiply the carrier frequency by the PRN sequence and then demodulates the incoming signal by the composite signal (PRN and carrier), and the data may also be filtered to produce the I channel and Q channel and also, need to display the number of bit errors and the bit error rate.

QPSK Modulation

The carrier frequency will be modulated by the spread data and also modulated by outspread data for comparison purposes.

IQ Channel

This file may generate the data and splits it into I channel and Q channel.

QPSK Demodulation

This file will demodulate the outspread signal for comparison with spread spectrum signal and need to display the number of bit errors and the bit error rate.

PN Sequence Generation

PN code sequence should generate both I and Q channel spreading sequence three shift registers combined to output a specific bits, and pseudo-random will isolate two separate PRN codes as one for I channel and one for Q channel. Said code should keep provision for modifying the bandwidth of PRN sequence [19].

Noise and Jamming Signal Generation

a. This record needs to deliver both discretionary noise and a jamming signal.

b. Amplitude of unpredictable noise will be set by changing estimation of variable $J0$, and amplitude of jamming signal is set by changing estimation of $N0$ ampleness of both is set in regard to nature of transmitted banner (which is set to 1) by using the equation of average bit error probability for a coherent BPSK system of DSS signal is $\mathrm{BER} = Q(\mathrm{sort}(Eb/(N0 + J0)))$ [20].
c. E.g. an estimation of 2 for "*a*" techniques the force of the jamming signal is twice as strong as the pined for transmitted banner at the recipient (If the UAV is closer to the jammer, then the jammer hail is more grounded than the transmitted banner paying little heed to whether both were a comparative power when they got out their source.)
d. Jamming sign will insinuate BPSK modification which seemed like a really practical adjust plot for a jamming signal.
e. One can make greater variety in the sorts of impediment signals created to fuse the pined for jamming signal [11, 12].
f. QPSK picked one of the four possible conveyor organize shifts (0, 90, 180, or 270 degrees). QPSK empowers the banner to pass on twice as much information of DSS input movement closes by jamming signal.

Direct Sequence Spread Spectrum Transceiver System With Time-Synchronization Considerations

- Produce a casual incentive for each part utilizing the random number generator. The variable got for every part take over the incentive between (0, 1) with equal probability.
- Determining the segment within the grid within the base TTF.
- Generate direct sequence spread signal with single tone jamming function through QPSK modulation under various jamming amplitudes.
- Physical layer jamming and noise attacks.
- Cooperative spectrum sensing with energy detector for smart grid is utilized for reducing time latency. So, utilization of a compressive receiver model as well as versatile flag extraction leads to incorporation of plan and recreation of a jammer system. Th catching of the DSSS transmitted flag that has been ruined with AWGN is the major task of a jammer [21].
- Results BER are plotted for DSS versus BPSK for proposed smart grid.

Simulation Setup

MATLAB software is used for simulating the proposed smart grid communication framework. MATLAB is a discrete-even simulator that equips varieties of engineering and technology toolboxes. Monte Carlo system is one of the great, productive techniques to assess the unwavering quality of the power distribution grids system. So, 34- node test system CTSF is used to simulate and used for utilizing the MCS method, to analyse jamming effect based on direct spread spectrum for smart grid. The demonstration over the effect of the smart grid technology has been done by MCS MATLAB code and also in improving the reliability indices of the TEST FEEDER. We implemented the IEEE trial framework the well-known two-state Markov model to the whole sum of the non-source constituents within the feeder. The Markov model has been divided into two states; first one is up which is for the sections working conditions, second one is down which explains failing state. The up state is being referred to as TTF (time-to-fail), while the down state is being referred to as TTR (time-to-repair/replace). Both TTR and TTF are unpredictable in nature. The procedure from up to down is known as the failure process for a part because of possibility occasion that would remove it from operation. Data of modelled 34-node test CTSF system utilize the MCS technique for further system. The proposed PLoSSI system possesses three modes: mode '0' for channel setup, mode '1' for CTSF 34–node test feeder data of smart grids and mode '2' for Markov model of CTSF 34–node test feeder data of smart grids, respectively. Further, the random noise level is varied from 0.4 to 4 for jamming signal and set relative strength of jamming signal to 0.4 to 4.

Result and Discussion

Jamming evaluation process based on performance is engaged with the interference evaluation comprised within the PLoSSI approval, PLoSSI execution with implemented DSSS and jamming computation prerequisites for the different levels of random noise level and relative strength of given input jamming signal.

The parameters required as a baseline for BER receiver simulations are stated in Table 1.1. In this work, the simulation is being considered as the total of CTSF 34—node test feeder data are considered as mode '0' with channel setup, mode '1' with CTSF 34—node test feeder data of smart grids and mode '2' with Markov model of CTSF 34—node test feeder data of smart grids.

Table 1 and Figs. 8, 9 show that this proposed PLoSSI along DSSS as BER versus rate and from the figure it is possible to observe that BER of the mode1 and mode2 of 34-node test feeder data and its Markov model of smart grids is less than 50%.

Further, the proposed PLoSSI found robust for random noise level of jamming signal for tested CTSF node smart feeder.

In any case, it infers to vary r the jamming signal progressively remembering the true objective for overcoming the

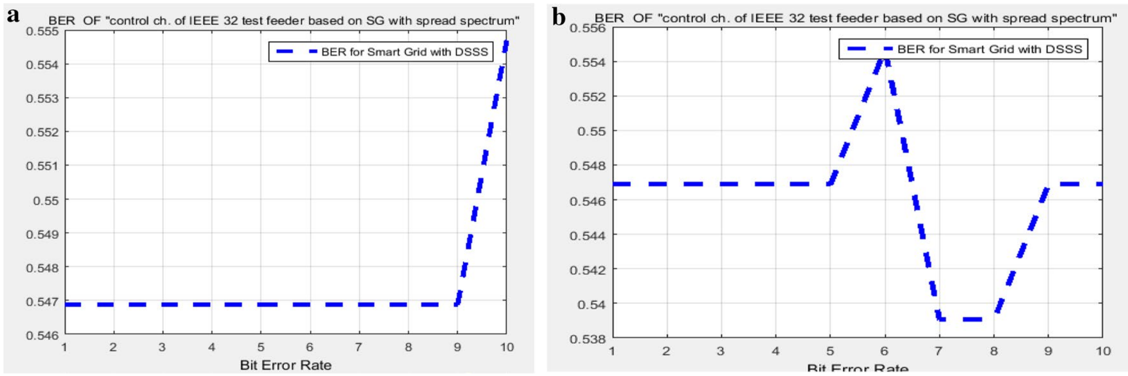

Fig. 8 **a** and **b** mode 0 with random noise level = 4 and relative strength of jamming signal 0.4 to 4 for BER and total error rate of proposed PLoSSI

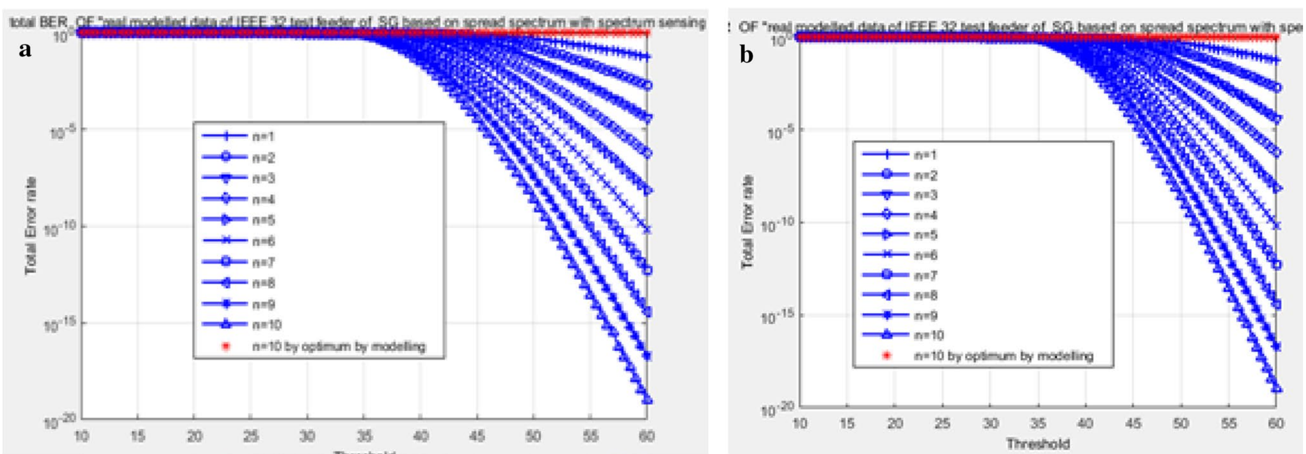

Fig. 9 **a** and **b** mode 0 with random noise level = 0.4 and relative strength of jamming signal 0.4 to 4 for BER and total error rate of proposed PLoSSI

processing gain. The DSSS transceiver viewpoint permits us to watch a particular BER performance for a given amount of energy per bit and also noise power spectral density that stays consistent even though when the interference average power varies with respect to average signal power.

Relative strength of jamming signals 0.4 to 4 for BER of proposed PLoSSI

Conclusion and Future Scope

This work gives a simulated perspective of varying jamming waveform parameters and how the jamming in DSSS can be optimized for smart grid. The transceiver model utilized for jamming assessment is developed with the idea of implementation and varying sequences or random noise level and relative strength with low complexity and good flexibility.

The CTSF node smart feeder and its markov model with DSSS simulated BER result in approximately 0.5 and robust for random variation in jamming signal as a consequence of the RF and dispreading filter incorporated to analyse the bandwidth effects on the transceiver before and after despreading the received signal. The jammer bandwidth choice is the most important parameter to degrade the performance of the spectrum sensing intelligence-based DSSS (PLOSSI) with matched filter implementation.

Future research areas that can be considered are:

1. Analysis of the effect of comparing different spreading sequences for the jammers evaluated in this work and the extension of long sequence to explore of the optimum bandwidth and jamming improvement factor for broadband jammers keeps similar proportion for large sequences in respect to shorter sequences for smart grids.
2. Analysis of the effect of variation in random noise and strength of the most effective jammers assessed in this work.

3. Study the signal jammers and the effects on synchronization [14].
4. Interference assessment under flat fading or selective fading. It implies channel estimation under the cases that the channel phase response is linear or when the channel gain and phase response vary with time and frequency.

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