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Security Enhanced Communication with Better Channel Encoders via Dc Micro Grids

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ABSTRACT

Power talk is a novel ultra narrow-band power line communication (UNB-PLC) technique for communication. Among control units in Micro Grids (MGs). Unlike the existing UNB-PLC solutions, power talk does not require installation of additional dedicated communication hardware and, instead, uses only the power electronic converters through which the control units interface the common bus. This way the communication system has practically the same reliability as the power system. The information is transmitted by modulating the parameters of the primary control, incurring subtle power deviations that can be detected by other units. In this project, we develop power talk communication strategies for Direct-Current (DC) MG systems with arbitrary number of control units that carry out all-to-all communication. We investigate two multiple access strategies: time-division multiple access, where only one unit transmits at a time, and full duplex, where all units transmit and receive simultaneously. We apply the concepts of signaling space, where the power talk symbol constellations are constructed, and detection space, where the demodulation of the symbols is performed. The proposed communication technique is challenged by the random changes of the bus parameters due to load variations. To this end, we investigate the performance of power talk when a solution based on training sequences that re-establishes detection spaces is employed. The presented evaluation shows that power talk has a potential to offer an effective and inexpensive solution for reliable communication among units in DC MGs.

INTRODUCTION

Communications over power lines have a history of more than a hundred years. The first applications required only very low bit rates, as they included control signaling, metering and load management. The rapid development of communications' technology recently made it possible to use the power line network for high speed transfer of data. Moreover, as access to Internet is becoming as indispensable as access to electrical power and the need for in-home local area networks is increasing continuously, power line communications (PLC) offer a potentially convenient and inexpensive solution. The unique fact that no new wires are needed, the availability of power outlets in every room and the easiness of installation give PLC the opportunity to compete with other "last mile" technologies, such as digital subscriber line (DSL), wireless local loop, wireless LANs and telephone lines. PLC access networks cover both the public area from the transformer substations to the customer premises

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(outdoor) and the private area within the customer buildings (indoor). Most of the systems available provide a maximum data rate of more than several Mbps.

However, power line grid can be characterized as a rather hostile medium for data transmission, because it was originally designed for the distribution of electrical power in the frequency of 50-60Hz. As a consequence, PLC channel faces some technical problems, such as impedance variations and mismatches, various forms of noise and narrowband interference, multipath propagation phenomena and high attenuation of the medium.

Further research should be carried out in the fields of efficient coding, modulation and transmission methodologies, in order to ensure reliable communication over power lines. Space-Time coding is a new coding modulation technique for multiple antenna wireless systems.

Multiplexing is an essential part in a communication system where multiple data streams are transmitted simultaneously through a single link. Multimedia data streams such as video, audio and high quality digital images have special requirements that are hard to be met, especially by power line communication systems (PLC). High bandwidth, small transmission delays and channel reliability are required for on-time data stream delivery and real time playback [1]. However, the nature of the transmission medium in PLC degrades significantly the performance, since attenuation and noise levels are often excessive [2, 3]. The proposed paper evaluates the performance of multimedia transmission in impulsive noise environments and presents methods to improve the Quality of Service (QoS). Additionally, an advanced multiplexing strategy combined with a forward error correction code is demonstrated and simulation results are provided.

THE increasing demand for data and voice transmission over the past years, has led to a “spectrum drought,” implying that alternative ways of communication are fundamental. Power-line communications (PLC) constitutes an innovative manner of information exchange. They imply transmission of the telecommunication signal through the public power network, which makes this new technology appealing since the existing infrastructure is utilized and there is no need for new wires. On the other hand, there are several drawbacks concerning this technology, which need to be overcome for better system performance. One main drawback is that the network was not originally designed for high-frequency signals; therefore, it introduces great variance to different signal components. Furthermore, due to the changing load on the power network, impulsive noise is added to the communication signal, which makes it even harder for the data to be recovered at the receiver.

In order to simulate a PLC system, it is essential that the channel characteristics are modelled. In the literature, there are several channel models available. One of the first channel models was introduced by Hensen and Schulz, which was a simple model implying that the attenuation increased with frequency [1]. “Philipps” model was introduced next, and took into consideration the multipath effect of the transmission through the power lines’ network [2]. This model is applied in the time domain, since it entails each path’s delay in time.

A frequency-domain channel model was introduced by Zimmermann and Dostert, [3]. This model not only estimates the delay that each path encloses, but also the attenuation that it undergoes due to the wire's length. Therefore, it is considered to be a more in-depth channel model. Moreover, Banwell and Galli proposed a channel model based on the multiconductor transmission-line theory, where, the power line can be represented by an equivalent circuit [4], [5]. Finally, there are several channel models introduced by various researchers which are based on measurements [6]–[8]. In this paper, Zimmermann's model is used, because it is easy to apply. It takes many parameters into account and is used a lot in the literature as a reference channel model.

It should be also mentioned that the telecommunication signal suffers deterioration due to the noise added by the channel. The noise can be divided into two categories: 1) background noise and 2) impulsive noise. Similar to the occasion of channel models, there are several noise models available in the literature for background and impulsive noise. The majority of these models are based on measurements. Some examples of such models can be found in [9]–[15]. One popular noise model used by a lot of researchers in the literature is Middleton's model [16], which we also take into account in our study.

According to this model, the total noise consists of two parts, describing the background and impulsive noise, respectively. However, according to [15], it does not describe impulsive noise in the most accurate way. Therefore, we introduce a new way of estimating the impulsive noise by exploiting the noise bursts' properties. According to these properties, noise bursts are Poisson distributed with an impulse arrival rate of

$$0 \leq \lambda \leq 5 * 10^{(-3)}$$

whereas their duration takes no longer than 0.1 ms [9]. Keeping these properties in mind, the impulse noise's effect on our data can be easily derived, as explained further in the next section.

In order for a complete PLC system to be simulated, coding and modulation techniques should be implemented. In this paper, we introduce array codes and specifically generalized array codes (GACs) and row and column array codes (RACs) as the system's coding scheme. These codes are mainly examined by Soyjaudah, [17]–[19] and Feng [20], [21]. However, never before have they been used in a PLC environment. Thus, it is practical to study their effectiveness in a PLC channel.

EXISTING SYSTEM

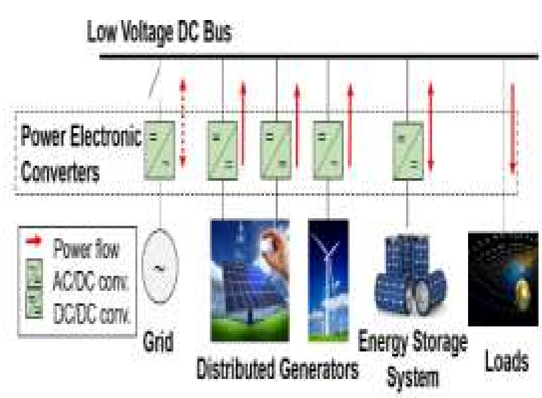

Figure 1. DC Microgrid

Existing systems have communication between DC bus, where it is an integral part of a macro or micro power grid. Ac power is invariably derived from non-renewable energy sources such as thermal power plant. Micro grids are realized using wind mills, solar panels and fuel cells. There exists huge

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load current variations in the cable meant for our communication. Hence, data loss and its associated minimization has not been concentrated in existing work. The transmitter end consists of a digital data source followed by encoder and modulator. Similarly, the receiver consists of decoder and demodulator. It is seen that no channel encoders are employed in earlier works. BER of existing channel completely depends on the amount of load current and hence any low pass filtering will lead to loss of data. In existing system, the power can flow from any direction to any direction, where bidirectional converters are employed. The following drawback is highly pronounceable in existing work. In this paper the existing UNBPLC standards are not directly applicable to DC distribution systems without a proper modification of the physical layer and they also demand installation of system-specific hardware.

PROPOSED SYSTEM

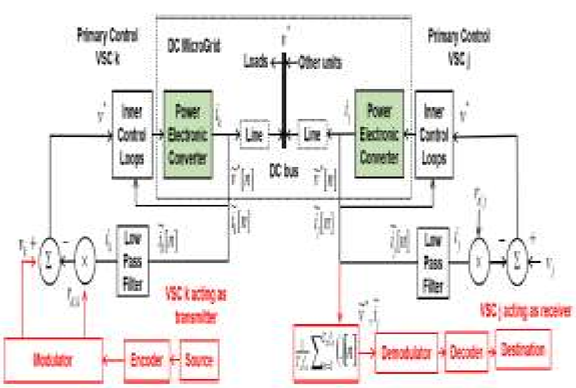

Figure 2. Communication in DC Microgrid

In this project, we develop power talk communication strategies for Direct-Current (DC) MG systems with arbitrary number of control units that carry out all-to-all communication. We investigate the effects that some exemplary solutions for coping with the sporadic load changes by resetting the detection spaces have on power talk rates. Finally, we investigate what is the cost of power talk in terms of power consumption.

We design power talk solutions for scenarios with multiple, all-to-all communicating units. The corresponding multiple access channel is realized in the bus voltage level controlled jointly by all units in the system. We apply the concept of signaling space, where the symbol constellations are designed such that the MG operation constraints are not violated.

TRANSMITTER AND RECEIVER (MODE 1)

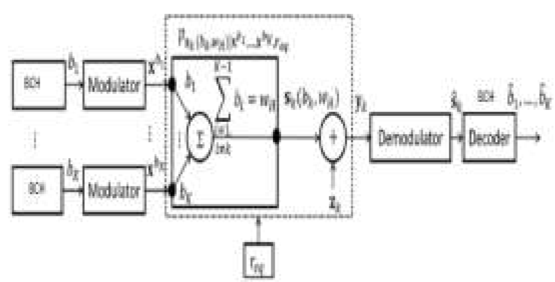

Figure 3. BCH encoder and decoder (Mode 1)

The data from the BCH coder is arranged serially with appended zero, in order to maintain the frame length. This coded data b1, b2….bn are modulated using, phase shift keying . The data sources from multiple data channels are multiplexed. X^{b1}, X^{b2}, X^{bk} are now added with a noise Zk is assumed to be added in data due to communication.

TRANSMITTER AND RECEIVER (MODE 2)

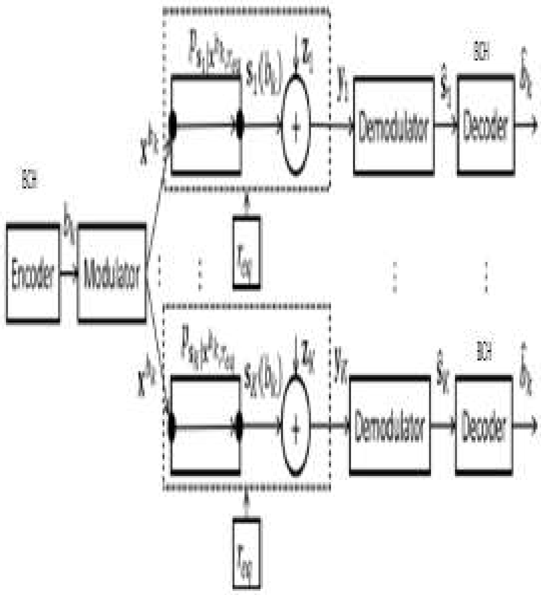

Figure 4. BCH encoder and decoder (Mode 2)

The MODE1 and MODE 2 differs just in the way that data is multiplexed at encoder stage or modulation stage. In mode 2, the data is multiplexed at encoder stage itself. The data from the BCH coder is arranged serially with appended zero, in order to maintain the frame length. This coded data b1, b2….bn are modulated using, phase shift keying. The data sources from multiple data channels are multiplexed. X^{b1}, X^{b2}, X^{bk} are now added with a noise Zk is assumed to be added in data due to communication.

BCH CODES

In coding theory, the **BCH codes** form a class of cyclic error-correcting codes that are constructed using finite fields. BCH codes were invented in 1959 by French mathematician Alexis Hocquenghem, and independently in 1960 by Raj Bose and D. K. Ray-Chaudhuri. The acronym *BCH* comprises the initials of these inventors' surnames (mistakingly, in the case of Ray-Chaudhuri).

One of the key features of BCH codes is that during code design, there is a precise control over the number of symbol errors correctable by the code. In particular, it is possible to design binary BCH codes that can correct multiple bit errors. Another advantage of BCH codes is the ease with which they can be decoded, namely, via an algebraic method known as syndrome decoding. This simplifies the design of the decoder for these codes, using small low-power electronic hardware.

BCH codes are used in applications such as satellite communications, compact disc players, DVDs, disk drives, solid-state drives and two-dimensional bar codes.

Primitive narrow-sense BCH codes

Given a prime power q and positive integers m and d with $d \le q^m - 1$, a primitive narrow-sense BCH code over the finite field GF(q) with code length $n = q^m - 1$ and distance at least d is constructed by the following method.

Let α be a primitive element of GF(q^m). For any positive integer i, let $m_i(x)$ be the minimal polynomial of α^i over GF(q). The generator polynomial of the BCH code is defined as the least common multiple $g(x) =$

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lcm($m_1(x),\ldots,m_{d-1}(x)$). It can be seen that $g(x)$ is a polynomial with coefficients in GF(q) and divides $x^n - 1$. Therefore, the polynomial code defined by $g(x)$ is a cyclic code.

The data to be transmitted is first source encoded and then it is applied to a bandwidth efficient encryption method. The key generated is equal to the number of data bits to be transmitted. The data is primarily exored with the key. The key is assumed to be known only to the receiver. Further the data is applied to BCH encoder in order to protect the data bits from noise. Then the data is further applied to the modulator where a PSK is employed. At the receiver end, exactly reverse process is carried in order to extract the transmitted bits. The communication part is implemented with script based programming and power system has been designed with Simulink block sets. A system with a AC generator with bidirectional converter has been taken as a power line communication platform. The data generated from the transmitter end after modulation is injected into the power system DC bus, and after it travels over several kilomters of distance and after a line impedance, the data is received using a simout block. This data is then exported to workspace where the demodulation and decoding process takes place. The modulated communication signals are in the range of -1 to 1 voltage and the DC bus voltage is in the order of 130V. At the receiver, this DC bias is filtered using a high pass filter designed with RC filter whose cut off frequency is given by fc= 1/ (2*pi*RC).

OUTPUTS

SIMULINK MODEL

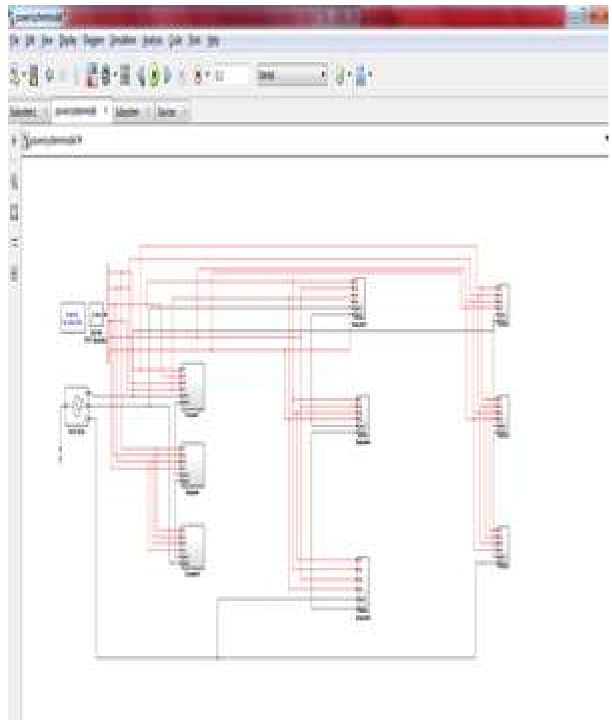

Figure 5. Simulink model

The Simulink model shown in the figure _, gives a functioning of power distribution system, where the AC power generated is rectified into DC. Further the DC is up converted or down converted based on the requirement using DC boost or buck converters. The diagram shows that, the system is capable of producing such 9 dc sources. In order to show the communication in between the DC channel, an example system is simulated using matlab version 2013 using power system and power electronics block sets.

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TRANSMISSION AND RECEPTION PART

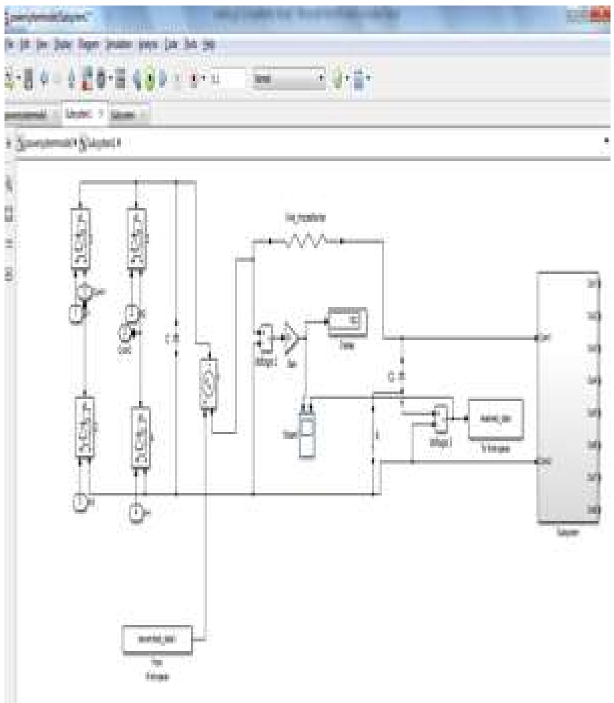

Figure 6. Data injection into DC grid

The Simulink model presented above is a sub system of previous Simulink model. This consists of a controlled rectifier and a DC bus ending up with another bidirectional DC to DC converter. Now our aim is transmit a data at the start of DC bus and receive the same at the end of DC bus. This is assumed to be communication channel in our experiment. The data is generated using matlab script and run separately and then the same is applied to this Simulink model by invoking the variables in matlab workspace. The data crosses all the way in noisy DC bus, and reaches the other part of the DC bus. The DC bus impedance can be adjusted in simulation as the Bit Error Rate required.

TRANSMITTED DATA

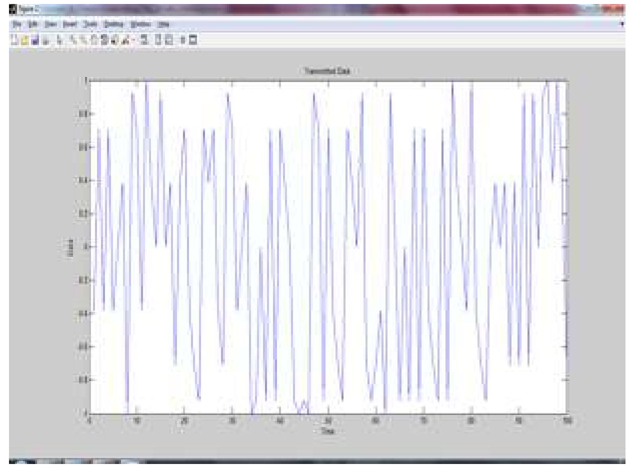

Figure 7. Binary data transmitted at 10dB

RECEIVED DATA UNDER 10 DB OF SNR

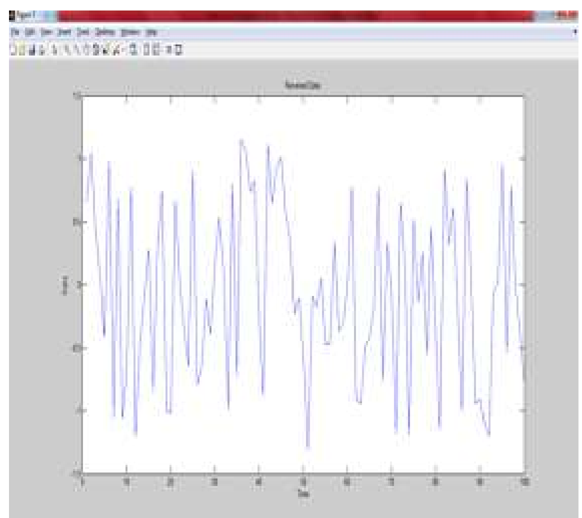

Figure 8. Received data at 10dB

The waveforms shown above are transmitted modulated signal at 10 DB of Signal to noise ratio. It may be seen that there exists huge changes in the received waveforms because of less SNR. Y axis is the real part of the

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modulated is signal, whereas X axis shows the time in seconds.

TRANSMITTED AND RECEIVED DATA AT 20 DB

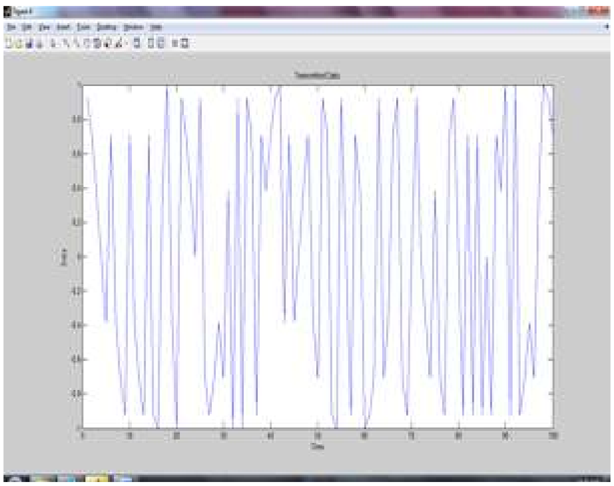

Figure 9. Transmitted data at 20dB

RECEIVED DATA UNDER 20 DB OF SNR

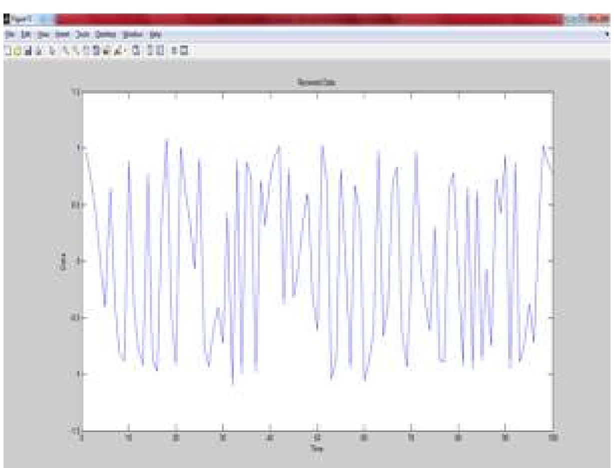

Figure 10. Received data at 20dB

The waveforms shown above are transmitted modulated signal at 20 DB of Signal to noise ratio. It may be seen that the received waveform is almost same as transmitted waveform because of 10 dB increase in SNR. Y axis is the real part of the modulated is signal, whereas X axis shows the time in seconds.

OUTPUTS SEEN IN POWER GRID (DC BUS SIDE)

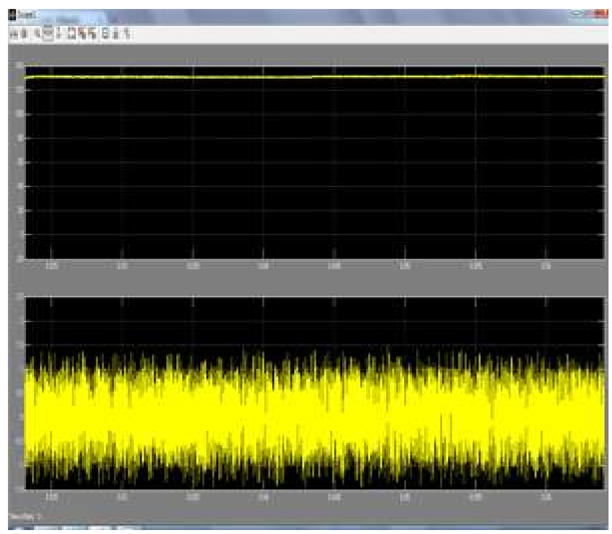

Figure 11. Data received in transmission line

The waveforms show the DC voltage and its corresponding data separated with 20000 samples. The DC bus voltage is around 130 V, which consists of communication data in the modulated form. The second waveform shows only the modulated communication signal, (real part of the signal).

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BER PERFORMANCE

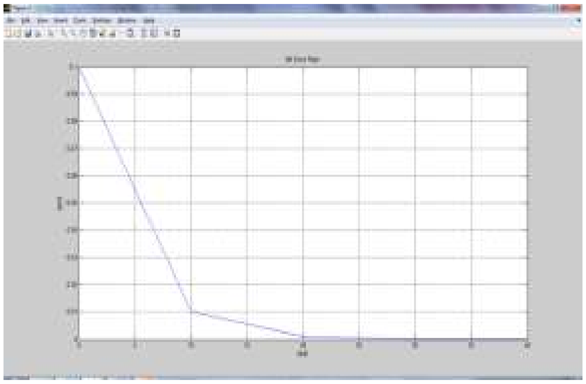

Figure 12. BER obtained

The above figure shows clearly that, the communication system performs well when operated with higher SNR. Since power channel occupied by noise fully, it is worse than the air media or common power free bus. We could achieve a least BER at 25 dB as seen in the figure. The following merits are enjoyed in proposed system.

1. Since BCH code is used BER in the order of 10-5 is achieved so as to ensure an errorless communication.
2. A cost effective method of encryption is used in order to protect the data transmitted from power stations.
3. The system is almost independent to the load voltage and current.

CONCLUSIONS

In this paper we presented power talk, a novel concept for communication among units in a Micro Grid. The core idea of power talk is to modulate information using primary control loops of the voltage source converters that regulate the bus voltage. A total of 400 samples have been taken and transmitted over a power channel under DC bus load conditions. The performance have been evaluated for various values of SNR ranging from 0 to 40 db. We have shown that it is possible to design power talk signaling constellations that conform to the operating constraints and power deviations limits. We have also shown that using MAP detector at the receiving end has an exception performance when the load (i.e., power demand) is stable, under mild constraints on the number of units in the system and allowable power deviations. The main challenge of power talk are random load variations, leading to the uncontrollable changes of the bus voltage. We investigated techniques to counter effect load changes, showing that it is possible to optimize the power talk operation given the statistics of the load changes. The achievable rates of power talk depend on the bandwidth of the primary control loops. In practice, it could be expected that power talk can achieve rates of the order of 100 Bauds. Nevertheless, considering that the inter-MG communications are machine-type in nature, these modest rates may prove to be satisfactory. Moreover, when assessing the potential of the proposed technique, one should also take into account its inherent advantages, which are use of existing MG power equipment, software implementation, and reliability and availability equal to the reliability and availability of the MG itself.

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