Chapter 5

# Architecture Parallel for the Renewable Energy System

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**Abstract**

This chapter present one possible evolution is the parallel topology on the high-voltage bus for the renewable energy system. The system is not connected to a chain of photovoltaic (PV) modules and the different sources renewable. This evolution retains all the advantages of this system, while increasing the level of discretization of the Maximum Power Point Tracker (MPPT). So it is no longer a chain of PV modules that works at its MPPT but each PV module. In addition, this greater discretization allows a finer control and monitoring of operation and a faster detection of defects. The main interest of parallel step-up voltage systems, in this case, lies in the fact that the use of relatively high DC voltages is possible in these architectures distributed.

**Keywords:** renewable energy systems, photovoltaic system, DC-DC step-up converter, distributed generator, power line communication

## 1. Introduction

In a constant effort to improve systems, numerous studies have used to find the best configuration to make photovoltaic systems more performing in terms of robustness and reliability. It now appears that systems distributed intelligence associated with distributed converters, constitute one of the most promising solutions [1–3]. Also our study will focus on the facilities of small powers that have good potential in terms of evolution. For those whom it concerns the higher power installations, the problems arise in another way. In fact, maintenance and production follow-up are provided by specialized teams, which is not always the case for small installations. We have also mentioned the possibility of opting for DC bus in the modularity of power generation. It is therefore more simply to consider transpose to small installations the modularity that is required in large power plants photovoltaic production.

One possible evolution is the parallel topology on the high-voltage bus shown in **Figure 1**. The system is no longer connected to a chain of PV modules but directly to the output of the PV module. This evolution retains all the advantages of this system, while increasing the level of discretization of the maximum power point tracking (MPPT). So it is no longer a chain of PV modules that works at its MPPT but each PV module. In addition, this larger discretization allows finer control of operation and faster fault detection.

The main advantage of parallel systems to step-up in the case that concerns us here is the fact that the use of relatively high DC voltages is possible in these distributed architectures, as also mentioned in their theses Estibal [2], Cabal [4], and Vighetti [5, 6]. The distributed structure is very advantageous both from the point of view of optimization and robustness to defects. It is also a modular application that allows for the multiplication and diversification of technologies, for example the combination of several types of photovoltaic sensors different with different renewable sources such as wind, hydraulic, compressed air, biomass.

**Figure 1** shows a possible configurational aspect. This is a DC voltage bus that can reach 1 kV. All panel-converter elements are connected in parallel "dubbing" on this bus. The

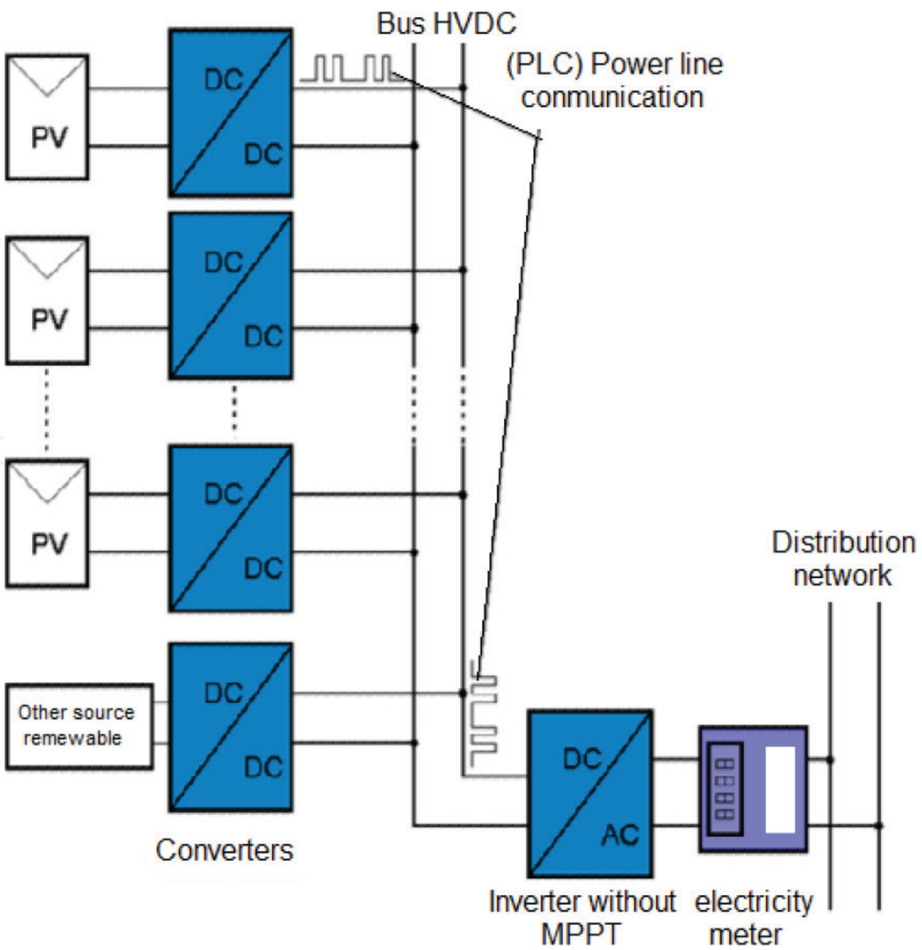


**Figure 1.** Diagram of a parallel structure on a continuous high-voltage bus.

phenomena of susceptibility to electromagnetic impulses (IEM) of lightning strikes on the DC bus are minimized by the use of twisted or very close cables, presenting only very small surfaces exposed to magnetic fields. Note the need for proper monitoring to avoid islanding. The downstream inverter does not manage the control of the overall MPP, as each panel is managed locally optimally. The case where several inverters are connected in parallel, for a question of power, does not change the question of control. The use of a high voltage makes it possible to envisage a reduction in the section of the cables, which constitutes a material gain in copper (or aluminum if necessary). The high voltage principle can be applied for voltages up to more than 1 kV. Some studies plan to push the limits to 8 kV [7], especially for the transport of energy produced by wind turbines. Raising the tension of a panel has many advantages. Without wishing to list them all, and at the risk of quoting the announcements of manufacturers present in this niche, we will retain some of the most remarkable aspects, namely:

- The constant output voltage of the converters makes it possible to directly attack an inverter.
- The resistances of the connectors are less critical at low currents.
- Contact quality problems are minimized by the use of high voltage. It is possible to use smaller cable sections as voltage is increased, resulting in a saving of copper (or aluminum).
- It is possible to use a DC voltage at the output of the converter.
- DC-DC risers are remotely controllable and are compatible with power line communication (PLC).
- The converters can locally provide the MPPT, which eliminates this feature of the inverter.

On the other hand a certain number of problems are inherent to the high tensions:

- Continuous high voltages present significant risks in terms of fire, which imposes a suitable security device.
- The insulation must be neat.
- A single inverter is inefficient when the powers to be converted are low.

This system using a high-voltage DC bus will allow, with appropriate adaptation, the supply of energy from several sources such as photovoltaic, wind, etc. to the output inverter. Although this technique was described many years ago, the generation of high DC voltages with good efficiency is not easy especially for DC-DC inverters with an output voltage greater than 10 times the voltage input.

### 1.1. Serial converter connection

The galvanic isolation of the output allows several DC-DC converters to be connected in series by simply connecting the positive output of one converter to the negative input of the other (**Figure 2**). In this way, non-standard voltage rails can be generated, however, the output current of the high voltage converter should not be exceeded. If the required output voltage of a converter is greater than the nominal voltage of the next converter, the outputs of both

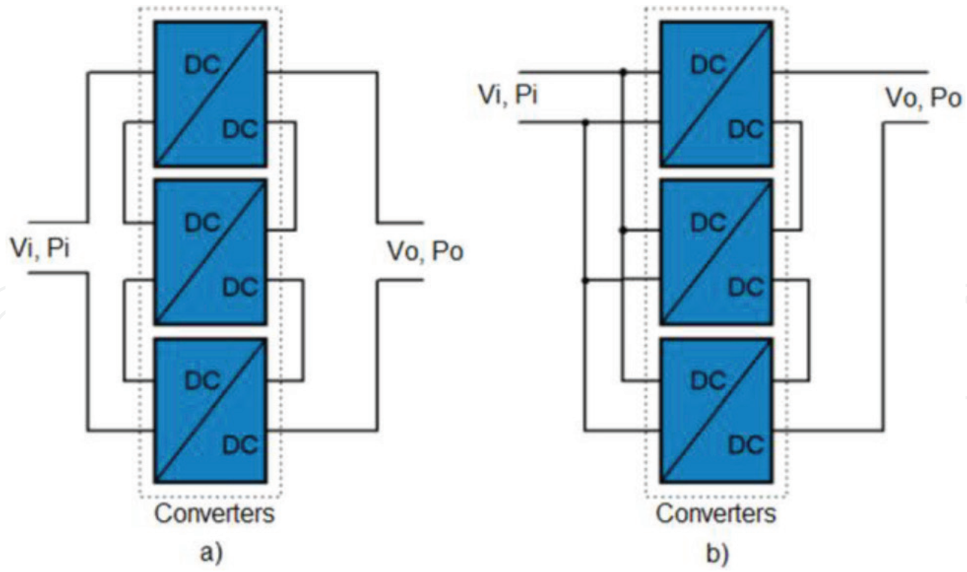


**Figure 2.** Serial connection of converters: (a) serial inputs and outputs, (b) parallel inputs and serial outputs.

converters can be connected in series in order to reach the desired output voltage. It is recommended that two converters of the same model be used for this application. The high isolation of the converter outputs allows multiple converters to be connected in series by simply connecting the positive output of one converter to the negative terminal of the other as shown in **Figure 2** [8, 9]. For this series mounting, the designer must also ensure that the total output voltage does not exceed the output breakdown voltage of the output for each converter.

When the converters are connected in series, additional external filtering is strongly recommended because the converter switching circuits are not synchronized. It is possible that there is a phase summation of the ripple voltages of the two converters resulting in relatively high beat frequencies.

### 1.2. Connecting converters in parallel

In power augmentation applications, DC-DC converters are often connected in parallel (**Figure 3**) to form a more robust power distribution system and produce higher currents. This distribution mode is commonly used for applications requiring high currents. The voltages can also be very low, for example in the case of a microprocessor supply. Compared with a single high-power converter, paralleling allows, by a homogeneous distribution of power, to reduce the stress endured by semiconductors and thus to improve reliability, robustness and service life conversion stage. This structure also provides a degree of freedom, in terms of flexibility and modularity, compared to a conventional converter.

The energy transfer converters cannot have exactly the same electrical characteristics, because of a dispersion of characteristics on the electronic components constituting them and a slight difference of connections. In operation, this causes a natural imbalance on the distribution of currents between each converter. Thus, the probability that one or more converters operate with an excess of current compared to others is great. This phenomenon results in significant thermal stress in the most stressed semiconductors, so the robustness, reliability and service life of the system are reduced, canceling the initial advantages of the structure. In order to remedy this problem and to guarantee a homogeneous distribution of the current and therefore of the power, current regulation is indispensable in these parallel structures [10].

### 1.3. Cascading converter connection

Theoretically, the voltage gains of an inductively accumulating DC-DC converter tend to infinity for a unit duty cycle. In reality, this gain is limited by the series resistances of the components (inductances and capacitors) [11, 12]. This gain cannot, or difficulty, exceed 5 for a high duty cycle. The specifications impose a voltage gain of around 25. A simple DC-DC boost converter cannot achieve this gain. To obtain this voltage gain, it is necessary to use a cascading arrangement (**Figure 4**).

After introducing renewable energy resources for conversion into electricity, we have examined in this chapter the parallel structures of high voltage DC voltage booster converters for the optimization of energy transfer management renewable sources by power line communication (PLC). The different structures were presented considering the possibility of improving the efficiency of the system. This system has the advantage of communication between smart converters in the energy transfer process. The study of the modalities of this communication is the subject of this chapter.

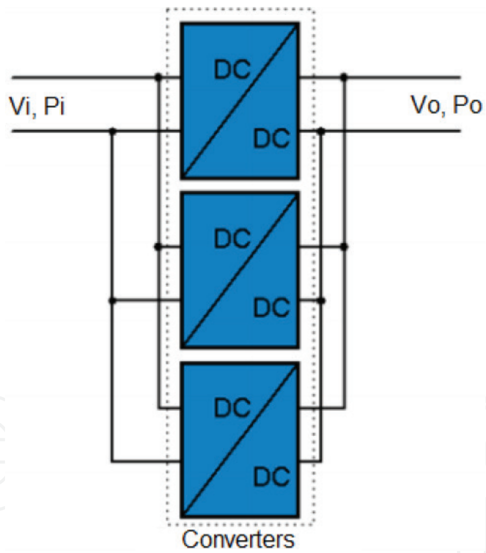


**Figure 3.** Connecting converters in parallel.

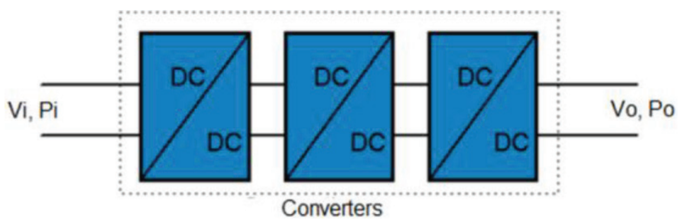


**Figure 4.** Connection of converters in cascade.

## 2. Distributed architecture for energy management and supervision of the HVDC bus by PLC

Investing and exploiting electricity distribution networks generated from renewable energy sources such as solar, wind, ocean waves, biomass … is a technological development to improve efficiency and stability. of all switching systems and power supply. With this affordable power distribution architecture, Smart Grid integration is a new option to optimize the output of each power source. This approach requires the addition in the system of intra and inter-communication tools with a central controller. A technical solution is power line communication (PLC) using the existing power line infrastructure for communication purposes. This new management capability improves performance and stability throughout the energy transfer process. In recent years, new energy supply concepts have been introduced. One of them newly introduced in renewable energy systems are smart grid concepts [13–15]. In addition, nowadays power-engineering field is facing huge challenges since the growing interest in intermittent renewable energies impose a whole new paradigm of operation. The use of these resources must be properly implemented to ensure safe, effective, autonomous and sustainable operations. At the same time, distributed energy sources are connected to each other to form a smart grid to provide adequate and reliable energy. Distance determination is made to provide energy for electricity used. Many of the energy sources in this proposal are of a continuous type and can be transformed before performing DC-AC transformations. With strong incentives for green energy, availability and advances in storage technology, the power generation in this smart grid proposal applies not only to distribution networks with coal or gas and burning, but also an incentive for anyone who wants to produce their own electricity. Data transmission is also required in the proposed Smart Grid concept based on the high voltage DC distribution system HVDC from renewable sources. The data transmission is necessary for the necessary functionalities and applications that will be integrated in the system, for example for the monitoring of the parallel DC-DC converter with power failure management and protection. For this reason, PLC is a possible alternative.

A possible answer to these challenges may be the solution proposed in **Figure 1**. In this figure presented in the above section, a power system consisting of various sources such as solar cells with different technologies, wind turbines and the system or any other dc power source interconnected by a high-voltage direct current DC storage bus compressed air energy (CAES); A regional power plant is composed of many small generators for internal lines, and a low cost overall structure [16, 17]. This structure shows the power on the HVDC line emitted from high-performance DC-DC converters. In the AC distribution network, a large DC-AC converter communicates between the HVDC and the AC network. Therefore, the HVDC system is designed to replace the traditional medium-voltage (MV) branch of the overhead line and distribute low-voltage AC by the HVDC distribution system. In this distribution network, the MPPT should be integrated in each DC-DC converter. In addition, these MPPTs optimize performance from each source, and the overall performance of the MPPT increases with respect to the central structure. In industry, the distribution and production systems of DC and HVDC are widely used and developed to replace AC power to DC. Moreover, there is an advantage of DC voltages for smart grids that do not need to be synchronized for decentralization.

In AC systems combined with intermediate HVDC lines, the quality of alternating current decreases at the output of the transmitter. This can be improved by reducing the number of branches of the MV grid and reducing the length of the line. Overhead lines can be replaced by underground low voltage cables. This has directly led to a decrease in the amount of defects generally occurring in MV networks. As a result, the quality and reliability of the distribution grid is improved and economic losses due to increased power quality are reduced. The HVDC bus with the configuration of the communication system is proposed when communication is made with the PLC. Therefore, the structure and configuration of the HVDC grid is related to a specific physical geographic area. This will bring restrictions to the controller, such as the reliability of the communication chain, the PLC loop is inserted. In addition, the inverters in the bus generate harmonics and interference on the transmission channel. All of these, along with some of the features that are implemented in the content grid to determine the boundary conditions and minimum requirements for PLCs. Thus, we can summarize that the main objectives of the development of distribution systems and continue for smart grids are the profitability and reliability of electricity distribution. Ubiquitous communication plays a key role in smart grids and HVDC concept presents a new approach for smart grid implementation [18].

The parallel modular structure topology shown in **Figure 5**. This structure is no longer connected to a chain of PV modules but directly to the output of the PV module. This evolution retains all the advantages of the "row" structure, while increasing the level of discretization of the MPPT. So it is no longer a chain of PV modules that works at its MPPT but each PV module. A productivity gain is therefore to be expected with respect to the "row" structure. In addition, this larger discretization enables finer monitoring and faster fault detection.

With medium and larger systems, it may indeed be advantageous to carry out MPPT initially by a DC-DC converter for each PV chain. Their outputs are connected to a DC bus, from which the synchronous inversion gate is made by a central inverter. If the nominal voltage of this DC bus is standardized, there is the possibility of integrating other generator sets (such as modular hydraulic systems or small wind turbines) as well. **Figure 6** illustrates the general concept of such a system.

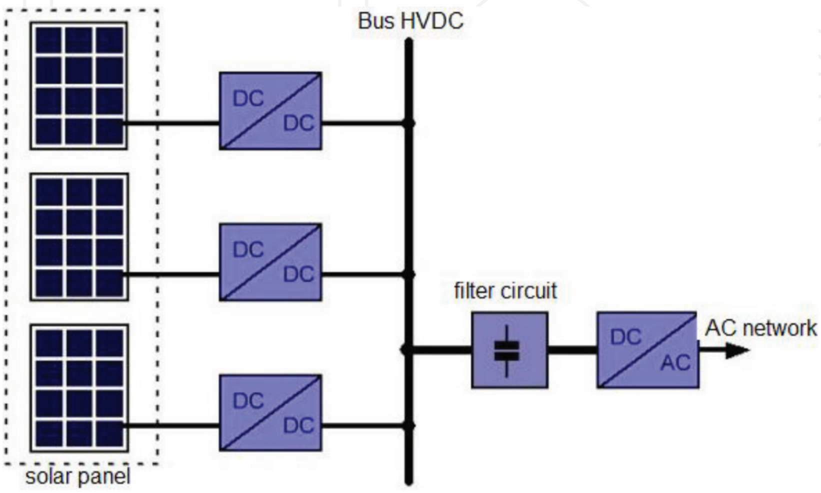


**Figure 5.** The main diagram circuit of a photovoltaic plane operating according to the mentioned method.

As shown in **Figure 6**, there are normally several DC-DC converters connected to the DC bus on the side of the generator, while the grid side of a central inverter goes on to power on the grid of electricity. The inverter should take exactly the amount of power from the DC bus that is fully supplied to the side of the generator.

Different operating states occur when the system starts up or when more power is available on the side of the inverter generator is capable of processing. How are these operating conditions managed? The requirements of stability, forgivingness, independent manufacturer compatibility and simple system design, can hardly be met by a digital bus system and a central control unit. The different operating conditions are rather to be detected by each component involved in an autonomous way. The necessary information will be extracted from the evaluation of the voltage level of the actual DC bus. **Figure 6** shows the operation of the ranges defined for this purpose.

The main hard point of this structure is the great ratio of elevation between the output voltage of the PV module types, different generators and the voltage required for the injection on the distribution HVDC bus. Indeed, for a non-isolated DC-DC converter the higher the elevation ratio the greater the losses. When this ratio is too important (>8 in general), it is necessary to use isolated structures or cascades of converters. In this case, the necessary elevation ratio is close to 10, which limits the efficiency of the DC-DC converter and penalizes this topology.

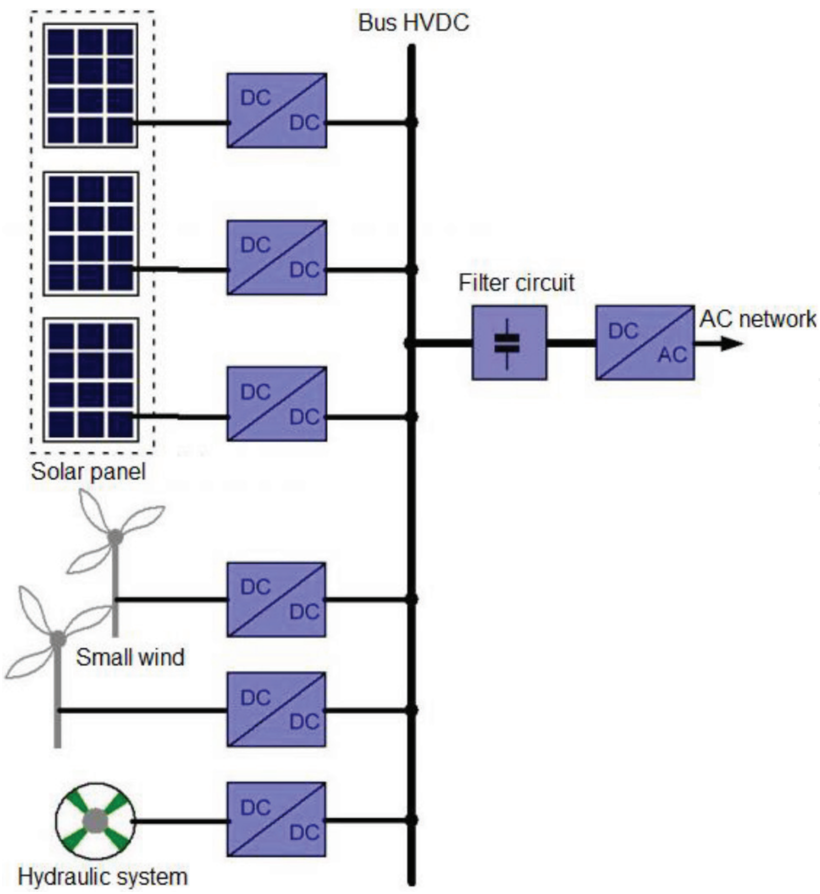


**Figure 6.** The general concept of a distributed electric power generation system.

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One of the main advantages of the HVDC system is the rapid controllability of the transmitted power. The power control in the HVDC system is based on current or voltage control, while minimizing losses in the DC line, it is important to maintain a constant voltage and establish the desired current on the DC line. The line from the rectifier to the inverter in order to obtain the desired power flowing in the DC line by varying the voltage at the converters. This method is important for voltage regulation in HVDC system to meet the examination of the optimal use of insulation and as we have noticed that the voltage drop in the DC line is reduced compared to AC the line due to the lack of reactive voltage drop.

Monitoring the transmission of energy with MPPT from separate renewable sources reliable, safer, more efficient and save. However, the installed consumers, the peak electricity demand would be so great that beyond the 3 kW power of an electrical system. The practical limit for the renewable energy transmission system is high that its output voltage to the inverter is generally low, beyond which the diameter of the wire becomes too large and cumbersome to handle. For a 60 V system, 50 amps implies power consumption almost 3 kW, it is obvious that a higher source voltage is needed to meet future demand on 3 kW. Without exceeding the limit of 50 amperes, 400 V is used. 400 V has been internationally agreed upon the maximum voltage that can be used safely in a conventional vehicle system without additional protection and also a 400 V system is capable of providing up to 19 kW without exceeding the current limit of 50 A of the wires. The general structure of a 400VDC power system is shown in **Figure 7**.

We present simple hardware of distributed architecture based on technical and performance requirements, proposed PLC architecture for HVDC currents. Commercial LC techniques and characteristic signaling methods are used. HVDC network links are recommended and evaluated by meeting the requirements set for that application. The distance between the mesh elements is evaluated by theoretical analysis and the actual data transfer test. Based on the DC-DC optimizer incorporates interface transformations, a PLC-based network architecture for HVDC line systems to meet all of these requirements. Note that a self-test step can also be added to the optimizer, but only the new PLC enhancements described in this section, the power conversion features, with their MPPT algorithms.

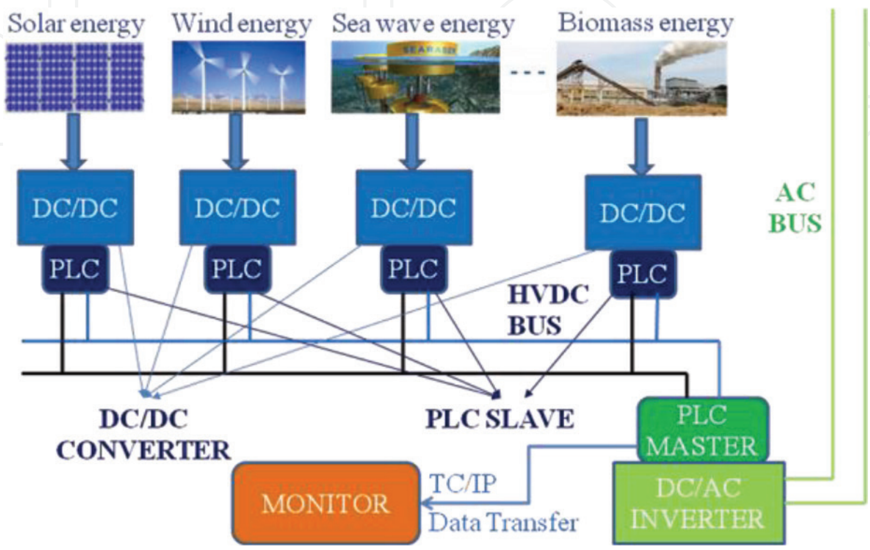



**Figure 7.** Offer PLC system on the HVDC bus.

PLC systems are installed in HVDC lines using clean inter-wafer circuits, used for insulation and impedance between the DC-DC converter and the power grid. It is possible to view PLC systems as an additional part of each converter, without modifying its basic structure. Nevertheless, the two main steps are driven by a common microcontroller peripheral interface (PIC) controller assuming both the controller's master–slave tracking and control functions. This system is required for communication in small and medium power systems, such as remote reading, fire/fire alarm control and shutdown. The system is designed with a digital modulator [19] to reduce the workload of the main controller of the DC-DC-PLC converter. These are two independent steps and a single control output reduces the cost of the entire system significantly.

## 3. PLC system design on the HVDC bus

Renewable system manufacturers' energy products increasingly differentiate their products by providing more sophisticated and inventive features such as safety, stability, control, comfort, convenience and performance. However, the use of these applications requires high volume data exchange and a reliable data communication network to enable efficient and efficient control over electronic devices. On the other hand, conventional infrastructure systems and distributed decentralized power generation systems transmit on high voltage lines, the PLC system does not affect the quality of energy transmission of the system. In addition, the nodes of the PLC slaves will be integrated in the DC-DC converter corresponding to each generator. Therefore, the design of the PLC system on the high voltage line is the simple, economical and reliable signal transmission.

In order to simplify and standardize the electrical system of the renewable energy generators on the HVDC bus, a number of communication standards and protocols have been proposed. Most communication systems on the HVDC bus are modified based on existing commercial communication technologies to meet the HVDC bus automation requirements such as high stability and error correction capability. In general, almost all networks for the HVDC bus are digital networks because of its high stability in terms of noise protection and error correction capability. From distributed architecture to decentralized renewable energy sources on high-voltage direct current transmission lines, we proposed to use Modbus protocol to implement the PLC system that we are designing. The Modbus protocol will be benthic in the next section.

### 3.1. Proposed DC power bus communication system

The basic idea of a power line communication system on the HVDC bus is to establish data communication on the DC line without installing additional wires. The simplified circuit of a PLC line carrier network is shown in **Figure 8**.

**Figure 8** demonstrates a simplified conventional circuit of injection of a sinusoidal wave or rectangle carrier signal to a DC power line with separation. Node 1 and the slave node and the master node are both in-line carrier communication transceivers which consist of a power amplifier for signal transmission on the HVDC bus. In this figure, $V_{conver}$ is the voltage of the DC-DC converter, $R_{conver}$ is the output resistance of the DC-DC converter, $V_{hvdc}$ is the voltage of the DC high voltage line, $V_{line}$ is the inverter input voltage, $R_{line}$ is the input resistance of the inverter, the signals on the line are the sine or rectangle to be injected into the power supply line and is amplified by a power amplifier. The transceiver output stage consists of an amplifier and a PLC interface signal circuit. DC carrier communication is a communication technology that makes use of the internal resistance of the power source and the parasitic components of the power cables and loads. The internal resistance of the power source is a designation factor of the performance of the communication from the power source is usually the component connected to the power line to the lowest impedance, the bulk of the power of the emitted signal would be dissipated to the power source. When node 1 is about to transmit a signal to the master node through the DC power line, the transited signal would first be amplified by the amplifier. The amplifier is usually a power amplifier to provide the signal power is appropriate because of the low impedance characteristic of the DC power line.

The transmitted signal moves through the cables of the DC line and is attenuated along the cables, a large percentage of the signal power is fresh at the impedance and parasitic components of the power line. By current the power line, the transmitted signal is attenuated and is

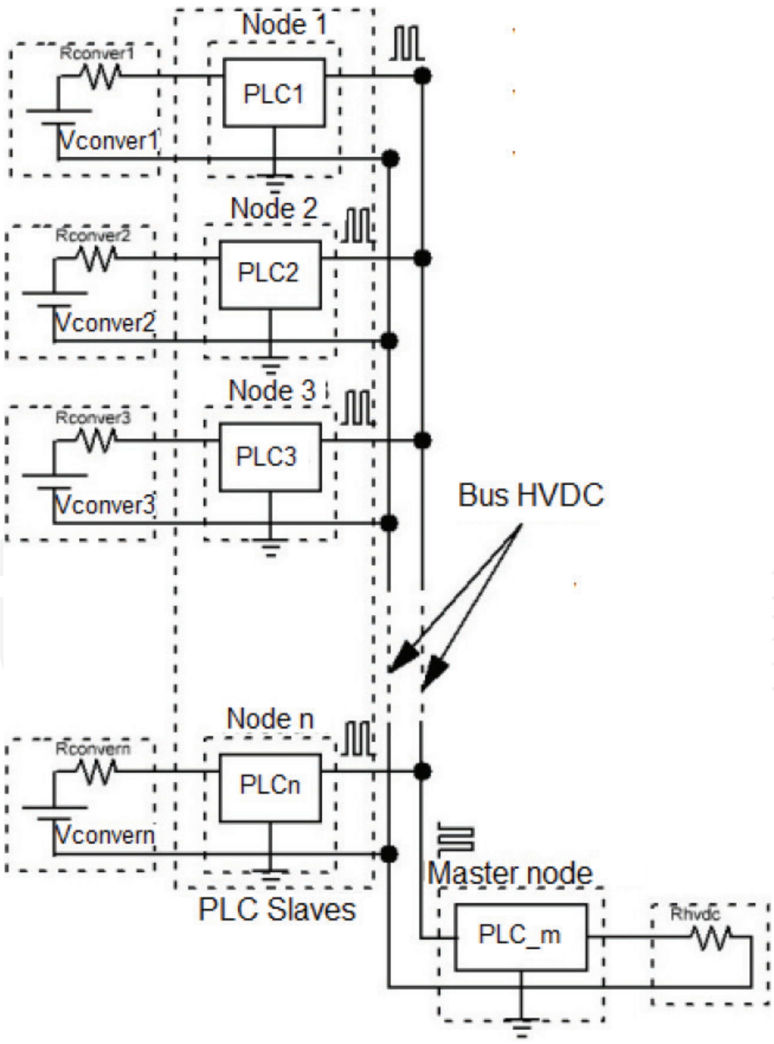



**Figure 8.** The general configuration of the renewable energy generator of transmission by DC-DC converters on the HVDC bus communication system with communication nodes.

sometimes distorted depending on the conditions of cable length and load of the power system. Upon reception, the detector reconstructs the deformed signal and filters the noise. The signal transmitted by the PLC slave node (1 − n) via the DC power line is then regenerated. **Figure 9** shows the simplified master–slave circuit PLC for using an amplifier to transmit the carrier signal to an HVDC bus.

### 3.2. Simple line current (PLC) on the HVDC bus

The basic operating principle of the proposed bearer transmitter was discussed. To facilitate "real" communication of dc line carrier data, other than the carrier signal transmitter, the system should consist of a dc line, at least one signal transmitter and a receiver signal, which is a simplex communication system. The simplified system design of DC simplex carrier communication using the proposed in line carrier transmitter is illustrated in **Figure 10**.

The function of the circuit shown in **Figure 9** is to transmit a data stream from the transmitter side to the receiver side, which is a very simple communication system that the data flows only in one direction, starting from the transmitter to the receiver. On the data stream is sent to the transmitter, it is coded, amplitude modulated and finally transmitted to the power supply network using the proposed carrier transmitter. Traveling through the power wire, the carrier signal is decoupled via a decoupling circuit at the receiver and demodulated in the original data stream. A simplex data transmission is then complete. The rate of the data system is set using 1 kbps ASK (amplitude shift keying) modulation [20]. ASK's help in the system is due to its simple modulation and demodulation processes. We have proposed a simple PLC, that the sender and the receiver are the same interface circuit so that other than the resistance and

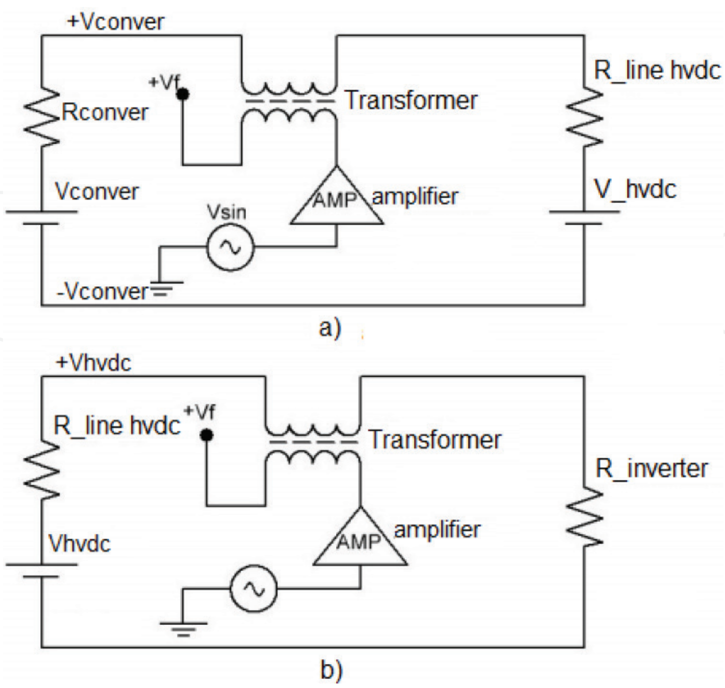



**Figure 9.** The carrier signal transmission circuit to an HVDC bus using an amplifier: (a) simplified PLC slave circuit; (b) simplified CPL master circuit.

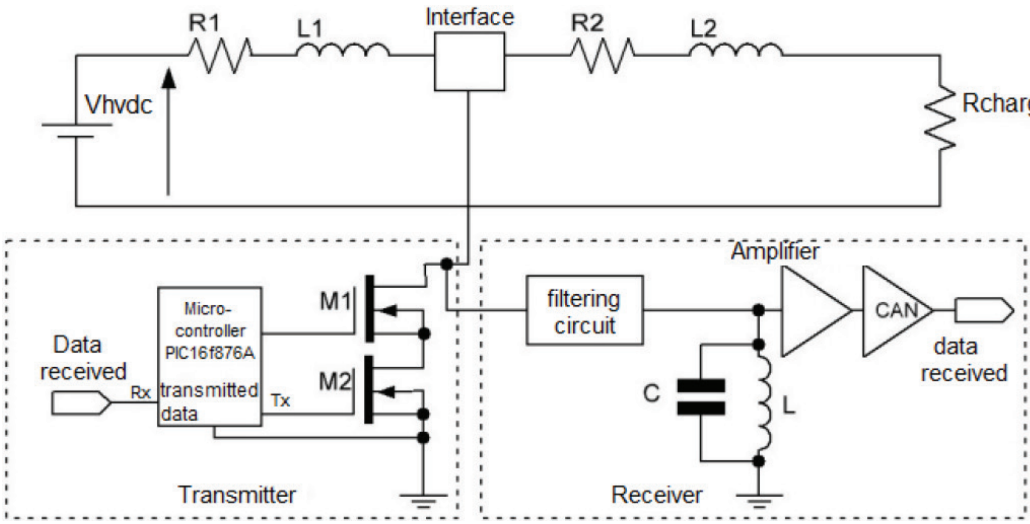



**Figure 10.** Diagram of the DC carrier communication system proposal with simple communication.

parasitic components of HVDC bus cables are not influencing that can be neglected. The resistors R1, R2 and Rcharge are three purely resistive loads connected to the HVDC bus.

To facilitate communication on the HVDC bus, the internal resistance of the DC power source (in this case the DC-DC converter) must exist from the converter is normally the component that carries the lowest impedance connected to the power line, most of the signal power delivered by the transmitter would be dissipated by the source into the DC-DC converter rather than distributed to receivers on the power line. This problem is important in communications on the DC system with a heavy load as the internal resistance is usually low in high voltage converter. To solve the problem, an inductance (this inductance Ls seen in **Figure 11**) can be added between the converter and the HVDC bus to increase the efficiency of the impedance of the DC-DC converter; therefore, the decrease in signal power dissipates to the converter. The value of the inductance is necessarily to optimize the value, a core inductor with a few tens of mH inductance is sufficient to increase the impedance of the converter.

The simulation circuit is shown in **Figure 12**. It is a DC simplex carrier communication system with a signal transmitter and a receiver. The system is powered by a 400 V converter, which is made up of 400 V $V_{hvdc}$ voltage source with a very low internal resistance so the jump. Since the resistor and parasitic inductance exist in virtually the cables and the transmitter and the signal receiver are always set apart along the power cable R2 are added to simulate the basic characteristic components of the cables. Since in practical power systems, the state of charge can be very complicated and unpredictable, to make the simulation simple, it is assumed that the resistor $R_{charge}$ is the only load connected to the net of power with the filter capacitor C1 connected in parallel. The operating principles and design considerations for a 400VDC net power communication system with multiple loads would be discussed in the last sections.

The simulation results are obtained using Pspice, which presents accurate models of the two passive and active components such as diodes and MOSFET transistors. The simulation describes how a digital signal flow is modulated in amplitude and transmitted on DC net power using the transmitter and the proposed support receiver in the steady state. Carrier

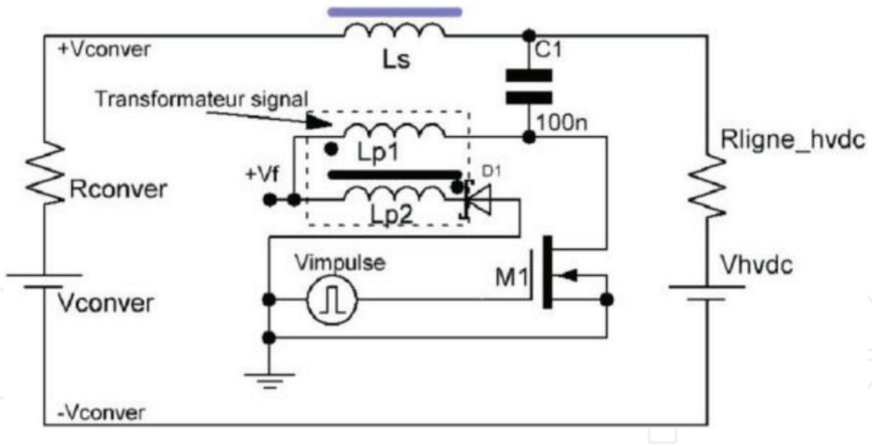



**Figure 11.** Schematic of the interface solutions in the PLC transmitting stage.

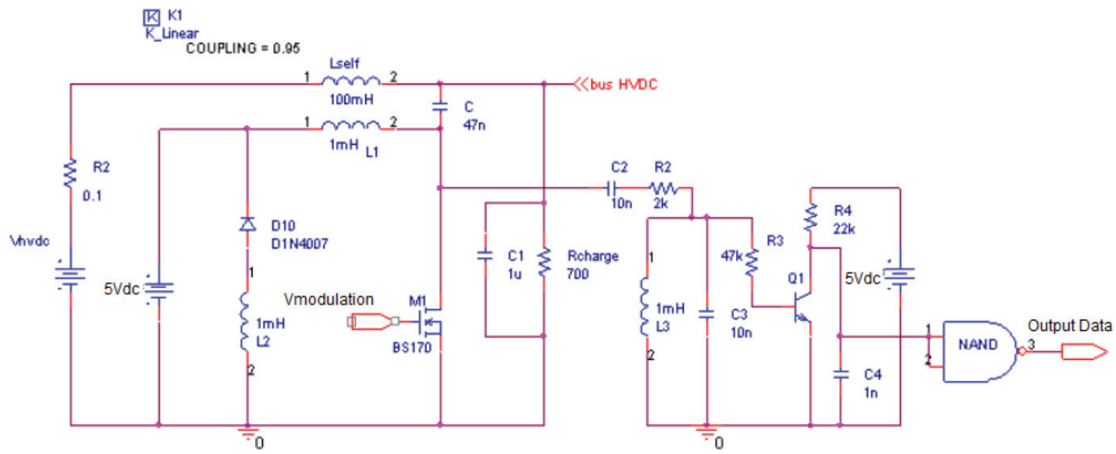



**Figure 12.** Simulation circuit of a simple communication system on the 400 V bus.

signal detection, demodulation, and error handling are not included in the simulation because these operations are performed by the program stored in the microcontroller. **Figure 13(a)** illustrates the waveform of the original data stream and the corresponding waveform of the amplitude modulated signal on the HVDC bus. In the simulation, the original data stream is implemented using a programmable logic pulse source "0" and "1" logic are represented by 0 and 5 V respectively. Since the transmitter circuit is only active when data transmission is required, in the simulation, the transmitter is off when the input signal is at zero volts. **Figure 13(b)** shows the ripple voltage of the HVDC bus during the transition to change the amplitude modulation. The transition time from logical state "1" to logical "0" is 10 μs. **Figure 13(c)** and **(d)** represents the voltage waveform of the inductor L2 and the drain of the MOSFET transistor M1 is compared to the original digital signal modulation.

The voltage regenerated by the current sensing circuit as a function of the filter capacitance current is shown in **Figure 14(a)**. **Figure 14(d)** shows the final output voltage of the entire receiver circuit. The output of the reception circuit is a series of rectangular pulses, where the time interval is equal to the modulation amplitude of the carrier signal; it is not yet demodulated since the signal demodulation and decoding tasks are performed by the microcontroller.

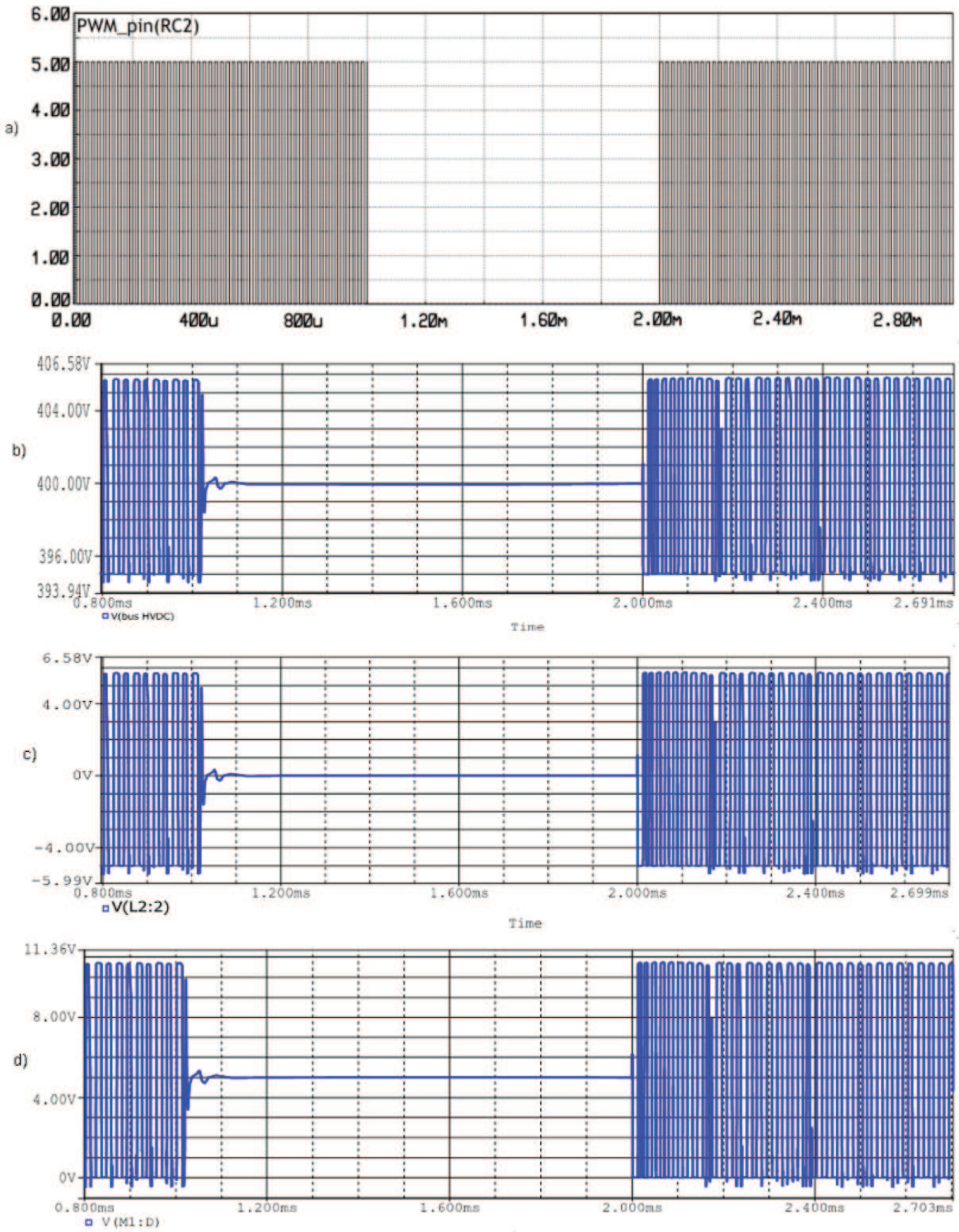



**Figure 13.** Simulation results at the transmitter: (a) PIC 16f876A microcontroller modulated signal, (b) 400V HVDC bus signal, (c) Signal curve at transformer inductance Lp2 also katot diode, (d) Amplified signal at drain MOSFET.

According to **Figures 13(d)** and **14(d)** in the figure, the control signal of the MOSFET transistor M1 is compared to the output signal of the receiver circuit. It is observed that the original data stream is successfully modulated, transmitted through 400VDC net power using the proposed transmitter and retrieved using the proposed receiver.

In the simulation, the signal modulator consists of a similar behavior model, the gain stages and limiters are implemented by ideal components. Since these elements practically do not exist, to verify the performance of the proposed net power DC communication system, an experimental device was built with the parameters indicated: the carrier frequency 50 kHz, the amplitude modulation at "0" equal to 0 V amplitude, the amplitude modulation at "1" equals the amplitude ±5 V, and the resistance of the HVDC bus equal to 10.

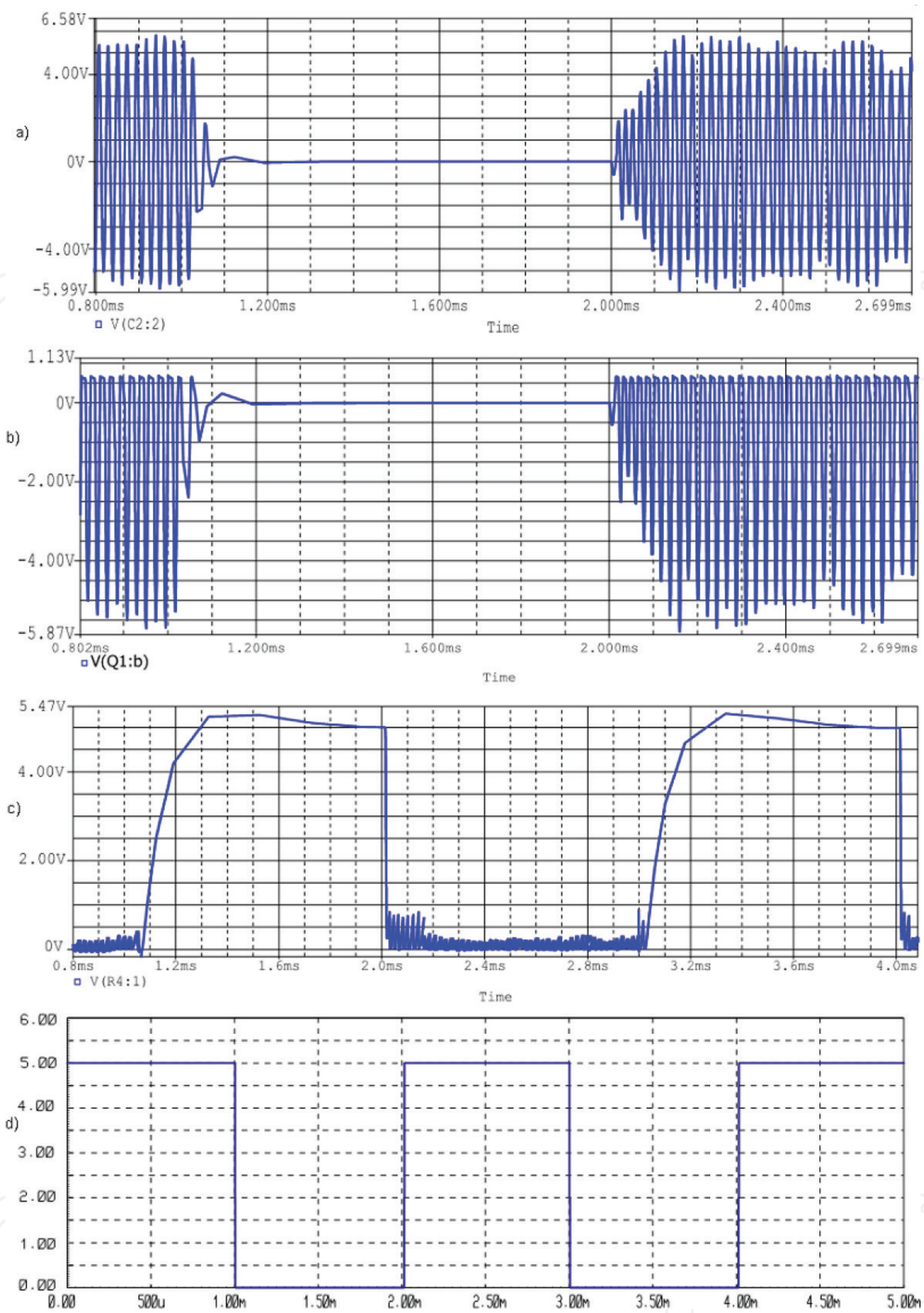



**Figure 14.** Simulation results at the receiver: (a) signal curve at the low band filtering circuit R1, C1, (b) input signal at the base of transistor Q1, (c) amplified signal at the collector of transistor Q1, (d) output signal A/D conversion.

The configuration of the experimental device is analogous to the circuit shown in **Figure 12** while the transmitter is controlled by a microcontroller and the output of the receive circuit is connected to a microcontroller for signal detection. In order to have a simple operating environment, a 400VDC net power communication system with a single resistive 10 Ohm bus is developed. The experimental results are shown in **Figures 15** and **16**.

In **Figure 16(a)**, the 400VDC net power signal is generated by a microcontroller with the proposed signal transmitter. The original data is modulated by the transmitter and transmitted to

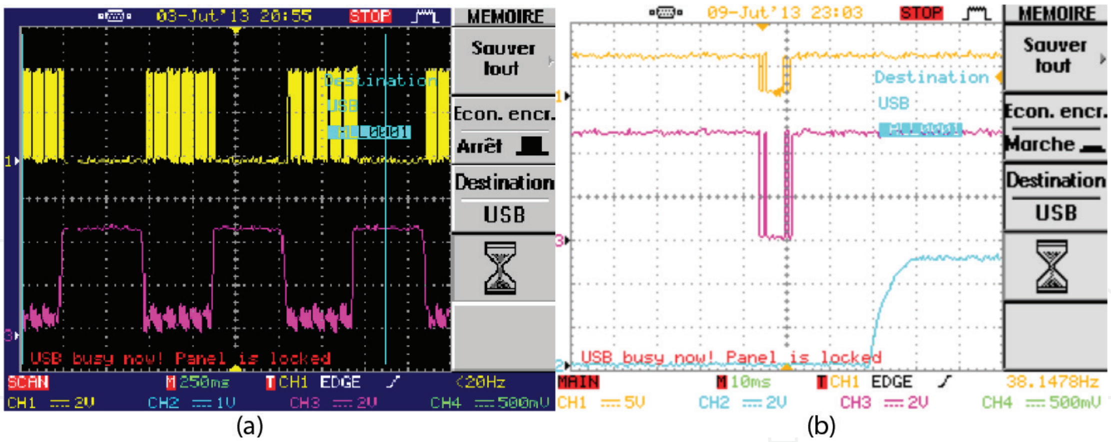



**Figure 15.** (a) Oscilloscope curves in model tests: yellow modulated signal with microcontroller of the transmitter and violet output signal of the receiver; (b) RS232 low data signal, positive logic: yellow TX/RC6 signal and purple RX/RC7 microcontroller signal.

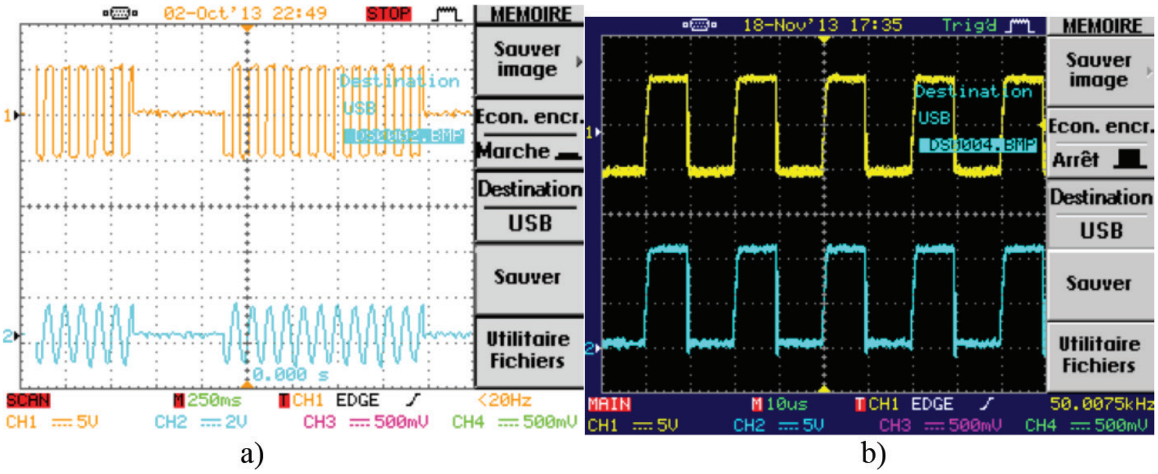



**Figure 16.** Curves obtained at the oscilloscope: (a) yellow signal curve transmitted on the line and blue output signal curve on the receiver filtering stage; (b) young Lp2 inductance signal and emitter drain signal M1.

the power supply in the form of voltage ripple, it can be seen that the original data is successfully regenerated by the receiver. The receiver output the demodulated signal after the whole packet is received with some delay. In the figures, we find that the experimental results show a good agreement with the initial forecast.

A power line communication system design for 400 V DC net power is presented in this section. The system is essentially a combination of communication system and power distribution system when the communication means is integrated into the power cables. In order to simplify the wiring structure and minimize the amount of system cables, the system structure is designed to be a bus network that the main power cable is pre-installed in the HVDC bus. The simulation results show that the data communication on a low impedance DC net power is achievable with the carrier signal transmitter and the proposed receiver. The main circuit of the transmitter is essentially a split-second converter with the input and output terminal connected together and operates in switching mode to achieve a high signal transmission efficiency. Being controlled by a microcontroller, the carrier transmitter is able to amplitude modulate and transmit a 1 kbps data stream to the power wire. Because the carrier signal travels through the power supply in the form of a ripple current that is filtered by the HVDC bus filter capacitors, to facilitate signal reception, the receiver is designed to be a coupler. Current that obtains the carrier signal from the current of the filter capacitors. The receiver behaves like a simple voltage converter current that converts the signal into sinusoidal coupled current pulses, where the period of the pulse sequence carries the fundamental frequencies of the modulation amplitudes. Signal demodulation and decoding processes are performed by the microcontroller with the program in the code. Practical implementation of the proposed DC net power communication is discussed. The simplicity of the proposed DC power net communication system, it is not only suitable for HVDC bus.

The approach chosen for the renewable energy generator, we have developed a PLC HVDC system based on two types of circuits for a slave circuit interface PLC dedicated to the individual optimizers, 2 a master PLC circuit, that is, the interface with the central management controller. Such a concept is shown in the **Figure 17**.

As a result of these prototypes, the experimental results were obtained even when the transmission module is plugged into the 150 m mains socket from the receiving module, **Figures 18** and **19**. The identification codes of the device sent on the line are correctly received and identified. by their slaves and corresponding devices. However, the circuit shows pick up stray electronic noise in the transmitter-receiver interface circuit of the PLC

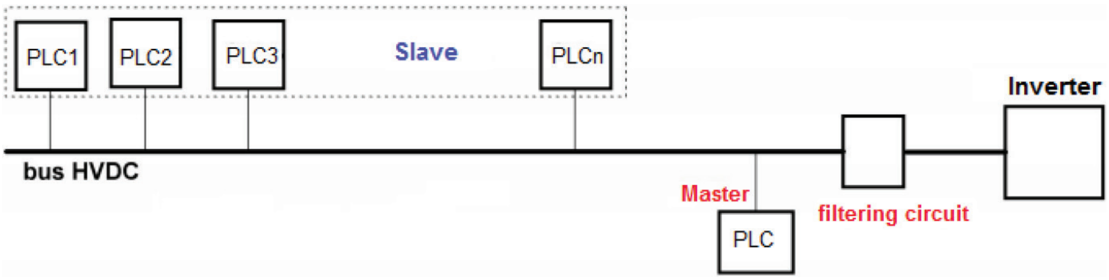



**Figure 17.** Diagram of master–slave HVDC PLC systems.

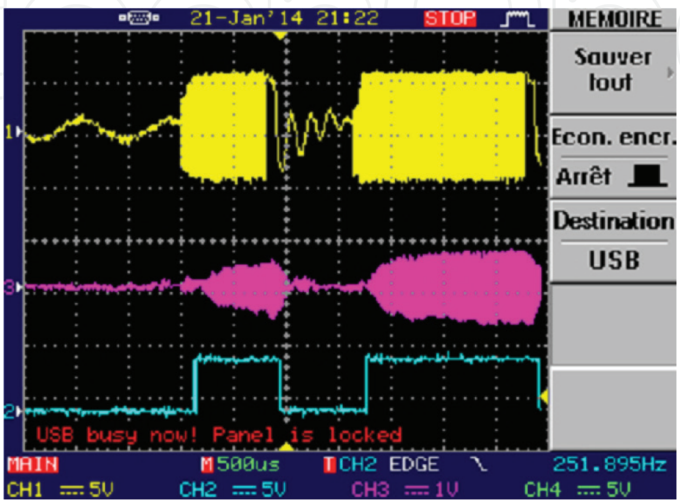
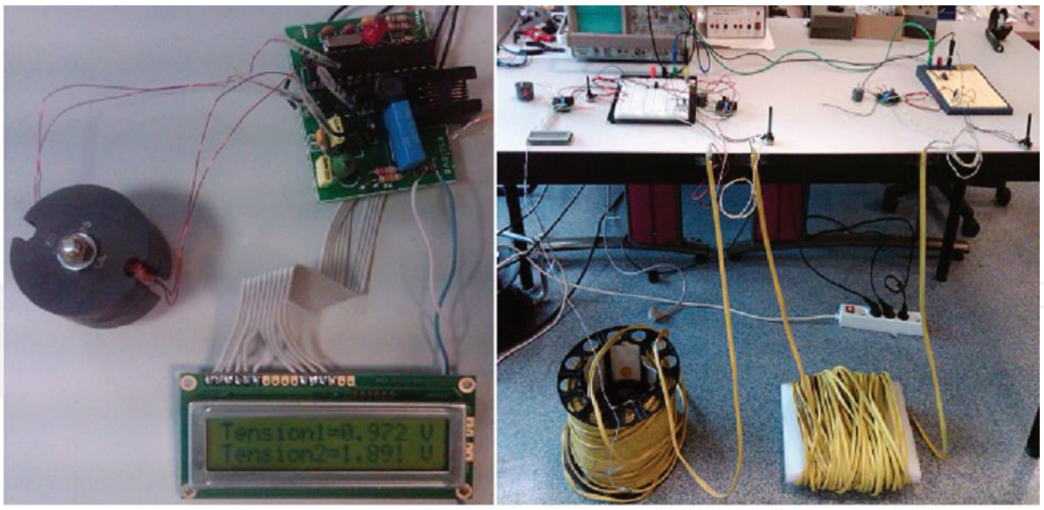



**Figure 18.** Slave PLC 1 (green signal) and 2 (blue signal) receiver data.




a) b)

**Figure 19.** The photos of the experimental in laboratory: (a) master CPL measures the voltages of the two slave PLCs; (b) experimental master PLC system-2 slaves on the cable 100 m.

on the HVDC bus. Thus, in the work in progress, the filter circuits must be modified to have high selectivity, which can be improved by increasing the order of the filter or replacing the passive with an active filter. The problem we are discussing has reeling cores self from PLC master of system.

## 4. Conclusion

In this chapter we have presented the new developments of dedicated communication system for distributed renewable energy generators. The work involved starts from the definition of constraints to be considered for this specific application to the full realization and testing of prototypes in real conditions. This electronic development is based on the hardware and software implementation of the slave and master modules of a power line communication (PLC) communication systems using the high voltage DC bus connecting all the converters of each DC-DC of the energy generator. The communication protocol used here is the widely accepted Modbus protocol. The communication has been successfully tested and is able to receive and transmit data without error on an experimental long bus. The system works as expected and has been tested to be showing a good response in a noise free environment. After this first realization proving the validity of our choices, work in progress focuses on the improvement of filtering circuits to increase the signal to noise ratio allowing a better selectivity in the information transmitted and detected.

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