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"A Dual SEPIC AC/DC Converter for DC Nano-Grid with Three Terminal Outputs"

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ABSTRACT

Due to the widely used DC characterized loads and more distributed power generation sources, the DC Nano-grid becomes more and more popular and it is seen as an alternative to the AC-grid. For safety considerations, the DC Nano-grid should provide reliable grounding for the residential loads as the low voltage AC power system. There are three typical grounding configurations for a DC Nano-grid, including the united grounding, the unidirectional grounding and the virtual isolated grounding. Each grounding configuration has its own specifications to AC/DC converters. In this paper a dual SEPIC AC/DC converter for use in the united grounding configuration based DC Nano-grid with three terminal outputs is proposed.

Keywords: characterized, Nano-grid, AC-grid, grounding, dual SEPIC

CHAPTER 1

1.1. INTRODUCTION

The distributed power generation is becoming more and more attractive due to the long term lack of energy and the environmental problems caused by the fossil energy. A large number of distributed generation systems, like photovoltaic systems, are today connected into the AC power system, where they can cause problems like voltage rise and also issue related to protection [. Further, more and more loads show DC characteristics, for example, LED lightings, computer power supplies, and also variable-frequency techniques based household electrical appliances. The DC Nano-grid may be a good solution to solve the voltage rise and protection problem of the conventional AC power system and can dismiss the traditional AC/DC converters for DC characterized loads, which may result in reduced power losses and material savings.

1.2 TYPICAL GROUNDING CONFIGURATIONS

In order to ensure the safety in the grid, most of household appliances are required to be connected with ground line, so in a DC Nano-grid as in a low voltage AC grid, ground line should be provided. There are three basic grounding configurations, which include the united grounding, the unidirectional grounding and the virtual isolated grounding. They will be explained in the following.

United grounding configuration, the AC low power system and the DC Nano-grid use the same ground line.The advantage of this configuration is that the DC Nano-grid can easily be installed into the original low voltage ACpower grid to form a hybrid power system.The disadvantage is that due to the low voltage devices, most of the original low voltage AC power systems cannot adopt this configuration and share the same ground line directly with a DC Nano-grid, if no special or complicated AC/DC converters are adopted. At the same time, the DC Nano-grid has to adopt a bipolar voltage structure with three terminal outputs.

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Unidirectional grounding configuration, the DC Nano-grid absorbs the power from the high voltage AC utility grid through a step down transformer, which works as an isolated transformer. Since the step down transformer offers a suitable low voltage for the DC Nano-grid,This AC voltage. For example a three phase step down transformer may output a 200 V phase to phase voltage rather than the standardized 380 V voltage. The AC/DC converter transfers the AC power into the DC power as the required DC voltage output and power rating. For example, the DC Nano-grid can be a single DC bus based system or a double DC bus system. The advantage of the unidirectional grounding configuration is that the AC/DC converter can use simple structure-converters like the two-level three-phase converter or the three-level three-phase converter or even other. The disadvantage of this configuration is that the output of the step down transformer cannot be connected with other low voltage AC residential loads directly.

Virtual isolated grounding,this method is similar to the unidirectional grounding configuration, while the transformer is connected with the low voltage AC power system instead of the high voltage AC power system. The advantage of the virtual isolated grounding configuration is that it is very flexible to construct the DC Nano-grid as required.

The disadvantage of the virtual isolated grounding configuration lies in the extra power losses brought by the additional transformer together with the possible more converters to be used. In theory, compared with the AC micro-grid, the DC Nano-grid can save more material and become more efficient due to the fact that less energy conversions are needed. However, as analysed above, currently, if the DC Nano-grid is connected with the AC power system using the virtual isolated grounding configuration, the efficiency of the

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system will be reduced, while if using the unidirectional grounding configuration, the flexibility of the DC Nano-grid will be limited. So it is necessary to develop a new type high efficient and low cost AC/DC converter for the united grounding configuration based DC Nano-grid.

1.3 OBJECTIVE

A dual SEPIC converter is used for united grounding based DC Nano-grid. By using this converter can reduce total harmonic distortion and switching losses.

CHAPTER 2

LITERATURE REVIEW

System operation and energy management of a renewable energy-based dc Nano-grid for high penetration depth application

A renewable energy-based dc micro-grid with hybrid energy storage, consisting of battery and ultra-capacitor, is investigated. To achieve high penetration depth of renewable sources into the utility grid, a novel system operation strategy and the corresponding energy management method is proposed. In the operation strategy, the ultra-capacitor unit works as the sole voltage source of the micro-grid to support the dc link in both connected and islanding mode. The micro-grid is controlled to deliver/absorb predefined amount of power to/from the utility grid during connected mode and zero during islanding mode. This design will certainly simplify the power dispatching algorithm of the power system and increase the possibility of including large quantities of micro-grids into the utility grid. The energy management method is dedicated to conducting the net power of the micro-grid effectively.

The net power is separated into high- and low-frequency components. The high-frequency power is suppressed by the ultracapacitor automatically and the low frequency power is shared by the battery and an adjustment unit.

Mode-Adaptive Decentralized Control for Renewable DC Microgrid With Enhanced Reliability and Flexibility ,

A mode-adaptive decentralized control strategy is proposed for the power management of a dc microgrid with multiple renewable distributed generators and energy storage systems. In the presented solution, the dc bus voltage signal is used not only to enable power sharing among different sources, but also to designate microgrid operation modes and facilitate seamless mode transitions. With this mode-adaptive operation mechanism, a greater control freedom can be achieved than the conventional dc voltage droop control scheme. More importantly, this approach features fully self-disciplined regulation of distributed converters without an extra control center or communication link. Therefore, both reliability and flexibility can be enhanced. Meanwhile, a novel mode definition criterion is also provided to highlight the special characteristics of the dc microgrid which is different from an AC one. Three typical operation conditions are summarized according to which type of sources are dominating the power balance. Finally, the effectiveness of the proposed technique is verified experimentally based on a composite dc microgrid test system.

Distributed Cooperative Control of DC

A cooperative control paradigm is used to establish a distributed secondary/primary control framework for dc microgrids. The conventional secondary control, that adjusts the voltage set point for the local droop mechanism, is replaced by a voltage regulator and a current regulator. A noise-resilient voltage observer is introduced that uses neighbours' data to estimate the average voltage across the microgrid. The voltage regulator processes this estimation and generates a voltage correction term to adjust the local voltage set point. This adjustment maintains the microgrid voltage level as desired by the tertiary control. The current regulator compares the local per-unit current of each converter with the neighbours' and, accordingly, provides a second voltage correction term to synchronize per-unit currents and, thus, provide proportional load sharing. The proposed controller precisely handles the transmission line impedances. The controller on each converter communicates with only its neighbour converters on a communication graph. The graph is a sparse network of communication links spanned across the microgrid to facilitate data exchange. The global dynamic model of the microgrid is derived, and design guidelines are provided to tune the system's dynamic response.

A Power Decoupling Method Based on Four-Switch Three-Port DC/DC/AC Converter in DC Microgrid

The proposed topology has three interfaces which can be connected with a dc source, a capacitor, and an ac port. With a corresponding power flow control method, this converter can decouple the low-frequency ripple power which is necessary for the ac port and undesirable for the dc source with small capacitor. The proposed topology is compact and cost-effective because, compared with the H-bridge inverter, no extra switches or devices are required. With the model of the proposed dc/dc/ac converter, a power control method with two inductors' current control is presented for power decoupling. In addition, the control parameters are designed as well. Experimental results on the laboratory prototype verified the feasibility of the proposed topology and the designed power control method.

Effective Test Bed of 380-V DC Distribution System Using Isolated Power Converters

The proposed test-bed system is composed of a grid-interactive ac-dc converter for regulating the dc-bus voltage, a bidirectional converter for the battery power interface, a renewable energy simulator, dc home appliances modified from conventional ac components, a dc distribution panel board, and its monitoring system. This paper discusses three isolated power converters, i.e., a bidirectional ac-dc converter, a bidirectional dc-dc converter, and a unidirectional dc-dc converter for the effective power interface of a dc bus. These isolated power converters are designed using a dual-active-bridge converter and the resonant topologies of CLLC and LLC. The proposed test-bed system was implemented using a 5-kW bidirectional ac-dc prototype converter, a 3-kW bidirectional dc-dc prototype converter, and a 3-kW unidirectional dc-dc prototype converter. Finally, the performance of the test-bed system has been verified using practical experiments of load variations and bidirectional power flow, employing the prototype converters.

A family of neutral point clamped full bridge topologies for transformer less photovoltaic grid-tied inverters

Transformerless inverter topologies have attracted more attentions in photovoltaic (PV) generation system since they feature high efficiency and low cost. In order to meet the safety requirement for transformerless grid-tied PV inverters, the leakage current has to be tackled carefully. Neutral point clamped (NPC) topology is an effective way to eliminate the leakage current. In this paper, two types of basic switching cells, the positive neutral point clamped cell and the negative neutral point clamped cell, are proposed to build NPC topologies, with a systematic method of topology generation given. A family of single-phase transformerless full-bridge topologies with low-leakage current for PV grid-tied NPC inverters is derived including the existing oH5 and some new topologies. A novel positive-negative NPC (PN-NPC) topology is analyzed in detail with operational modes and modulation strategy given. The power losses are compared among the oH5, the full-bridge inverter with dc bypass (FB-DCBP) topology, and the proposed PN-NPC topologies. A universal prototype for these three NPC-type topologies mentioned is built to evaluate the topologies at conversion efficiency and the leakage current characteristic. The PN-NPC topology proposed exhibits similar leakage current with the FB-DCBP, which is lower than that of the oH5 topology, and features higher efficiency than both the oH5 and the FB-DCBP topologies.

Maximizing power yield in a transformer less single-phase grid connected inverter servicing two separate photovoltaic panels

A single-phase grid connected transformerless inverter for solar photovoltaic (PV) systems is presented in this study. This inverter has the capability to extract maximum power from two separate PV panels operating under equal as well as mismatched meteorological conditions. The proposed inverter is based on the buck-boost principle, and hence, can tolerate a wide variation of voltage in both the PV panels. Further, due to the neutral point clamped structure of the inverter the neutral/ground terminal of grid is directly connected at

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the midpoint of two PV panels. This eliminates the flow of leakage current through the parasitic capacitances existing between the PV panels and the ground. The proposed inverter requires six switches and is free from shoot-through fault. This inverter does not require sensing of grid current for its operation. The principle of operation of the inverter is presented. The control strategy devised for the inverter is provided. The theoretical analysis is supported through detailed simulation studies carried out on MATLAB/Simulink platform.

CHAPTER 3

EXISTING SYSTEM

DC Nano-grid gets of more and more concern, especially for the control of AC/DC topologies, which are the connections between the DC Nano-grid and the traditional AC power system. It should be pointed out, when designing the AC/DC converters for DC Nano-grids, the grounding configuration needs to be addressed, since it determines the costs, the flexibility of the installation and also the efficiency of DC Nano-grid system. This paper analyzes three grounding configurations of the DC Nano-grid.Which include the united grounding, the unidirectional grounding and the virtual isolated grounding.United grounding configuration, the AC low power system and the DC Nano-grid use the same ground line.The advantage of this configuration is that the DC Nano-grid can easily be installed into the original low voltage AC power grid to form a hybrid power system. So the united grounding configuration is focussed for domestic applications.

CHAPTER 4

4.1.PROPOSED SYSTEM

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This project analyzes three grounding configurations of the DC Nano-grid. Then, a dual SEPIC AC/DC converter is proposed, which will facilitate the applications of the DC Nano-grid with three terminal outputs. Also, theoretical analysis of the proposed converter will be given as well as experimental verifications are carried out. In order to ensure the safety in the grid, most of household appliances are required to be connected with ground line, so in a DC Nano-grid, like in a low voltage AC grid, ground line should be provided .There are three basic grounding configurations, which include the united grounding, the unidirectional grounding and the virtual isolated grounding.

4.2 SEPIC AC/DC CONVERTER DESIGN AND OPERATION

The purpose of this project was to design and optimize a SEPIC dc/dc converter (Single Ended Primary Inductance Converter). The SEPIC converter allows a range of dc voltage to be adjusted to maintain a constant voltage output. This project talks about the importance of dc-dc converters and why SEPIC converters are used instead of other dc-dc converters. This project also goes into detail about how to control the output of the converter with either a potentiometer or feedback to show how it can be implemented in a circuit. From this project, one learns dc-dc converter optimization and control.

Introduction Circuits run best with a steady and specific input. Controlling the input to specific subcircuits is crucial for fulfilling design requirements. AC-AC conversion can be easily done with a transformer; however dc-dc conversion is not as simple. Diodes and voltage bridges are useful for reducing voltage by a set amount, but can be inefficient. Voltage regulators can be used to provide a reference voltage. Additionally, battery voltage decreases as batteries discharge which can cause many problems if there is no voltage control. The most efficient method of regulating voltage through a circuit is with a dc-dc converter. There are 5 main types of dc-dc converters. Buck converters can only reduce voltage, boost converters can only increase voltage, and buck boost, CUK, and SEPIC converters can increase or decrease the voltage.

Some applications of converters only need to buck or boost the voltage and can simply use the corresponding converters. However, sometimes the desired output voltage will be in the range of input voltage. When this is the case, it is usually best to use a converter that can decrease or increase the voltage. Buck-boost converters can be cheaper because they only require a single inductor and a capacitor. However, these converters suffer from a high amount of input current ripple. This ripple can create harmonics; in many applications these harmonics necessitate using a large capacitor or an LC filter. This often makes the buck-boost expensive or inefficient. Another issue that can complicate the usage of buck-boost converters is the fact that they invert the voltage. CÚK converters solve both of these problems by using an extra capacitor and inductor. However, both CÚK and buck-boost converter operation cause large amounts of electrical stress on the components, this can result in device failure or overheating. SEPIC converters solve both of these problems.

All dc-dc converters operate by rapidly turning on and off a MOSFET, generally with a high frequency pulse. What the converter does as a result of this is what makes the SEPIC converter superior. For the SEPIC, when the pulse is high/the MOSFET is on, inductor 1 is charged by the input voltage and inductor 2 is charged by capacitor 1. The diode is off and the output is maintained by capacitor 2. When the pulse is low/the MOSFET is off, the inductors output through the diode to the load and the capacitors are charged. The greater the percentage of time (duty cycle) the pulse is low, the greater the output will be. This is

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because the longer the inductors charge, the greater their voltage will be. However, if the pulse lasts too long, the capacitors will not be able to charge and the converter will fail.

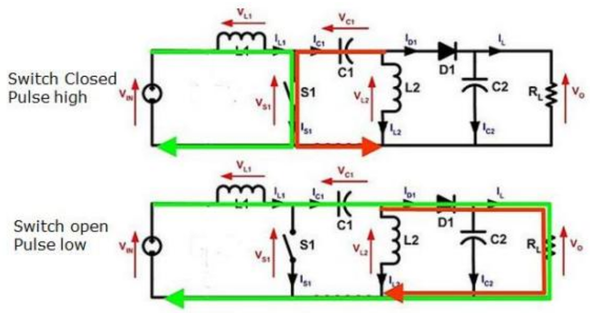

Fig 4.1: SEPIC operation

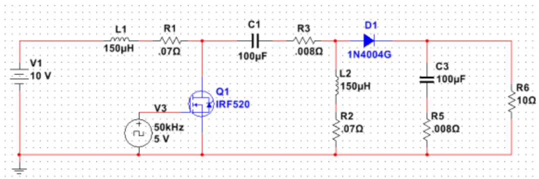

Fig 4.2:SEPIC Simulation

The SEPIC converter is able to either increase or decrease an input voltage by controlling the Duty Cycle of a pulse to the MOSFET. One way to do that is to directly control the Duty cycle using a potentiometer. There are some applications for which this control method is suitable but it is insufficient for many other applications.

In order to drive the MOSFET, a pulse is needed. A 555 timer is used to produce a square wave with a set frequency and a Duty cycle≥50%. However, the duty cycle from the 555 cannot be easily changed without switching resistors. In addition, the SEPIC requires a duty cycle below 50% to buck the voltage when the input voltage is low. The pulse width will need to be modified separately from the 555 because the 555 cannot change or produce a duty

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cycle less than 50%. First a resistor and a capacitor are used in low pass to produce a triangle wave from the square wave output of the 555. Afterwards, this is sent to the negative pin of a comparator. The positive pin of the comparator receives a controlled voltage signal. Whenever the controlled voltage is greater than the triangle wave, the comparator will output voltage and otherwise it will be off. The greater this signal, the greater the duty cycle of the comparator output will be. One way to control this signal is to step down voltage using a potentiometer. Luckily, this signal can be kept in the same range as the triangle wave by using the same input that drives the 555 timer. The duty cycle will not change when the input or the output voltage changes which means there is full control of how much the SEPIC steps up or down the voltage. This has both advantages and disadvantages for the circuit.

Full control of the circuit can be useful. The potentiometer allows the SEPIC to output a wide range of voltage from a wide range of input. This could be useful in battery applications that need to run on various levels of power. One example would be a flashlight with adjustable brightness. This SEPIC converter could allow it to run on a large range of power with greater efficiency than simply reducing the voltage with a potentiometer to control the output. However, this control method does have its drawbacks.

Most applications of the SEPIC converter control the voltage automatically. The problem with relying on controlling the input for circuit control is that there is no circuit feedback. When using a potentiometer, the only way to maintain the correct output is to watch the output and adjust accordingly. Visual feedback is only useful in certain circumstances. Usually it is best to use the SEPIC converter to hold a single output without the need for control when using a SEPIC as part of a large circuit.

Circuit Diagram

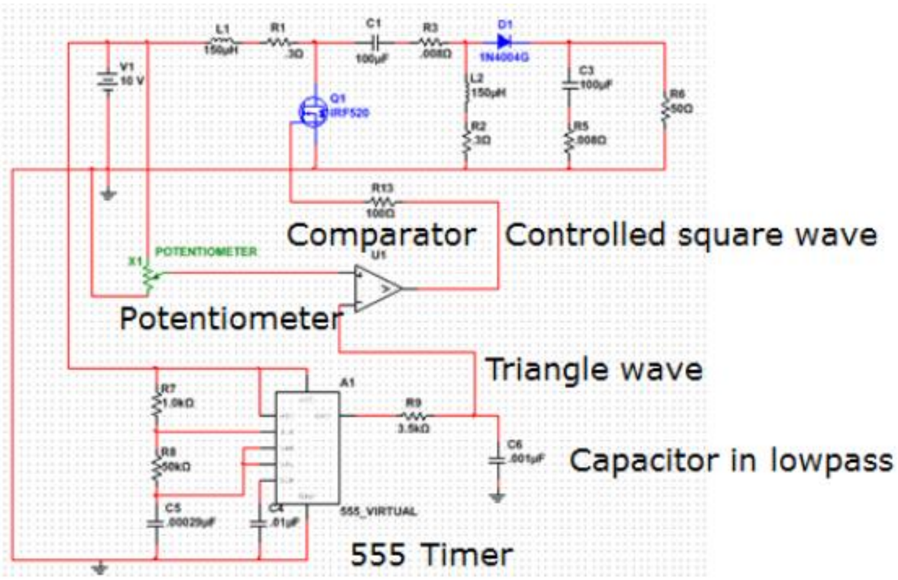

Fig 4.3:555 timer

Feedback Controlled PWM

While a potentiometer allows for control of the SEPIC converter output during operation, it is unable to hold a constant output with a variable input that changes. This is used in the majority of SEPIC converter applications which require automation to correct an input voltage. The simplest way to maintain a constant output is to use a feedback loop that will change the output automatically instead of by manual control (using visual feedback from a voltmeter). The feedback loop should be able to increase the duty cycle to raise the output when the output is too low and decrease it when the output is too high. To do this, the output will need to be compared to a reference voltage which remains constant even if the input changes. The error between the output and the reference voltage is then amplified and added to a set bias voltage. The resulting voltage is then used as the control voltage for

PWM. When the output is too low, the amplified error increases which causes the control voltage to increase.

The increase in control voltage increases the duty cycle until the output is correct. When the output is too high, the amplified error becomes negative which decreases the duty cycle to correct output. Both of these scenarios work together to constantly make slight adjustments to the duty cycle so that the output remains stable. The simulations for feedback show how the output changes with the gain of the amplifier.

Feedback Flow Chart

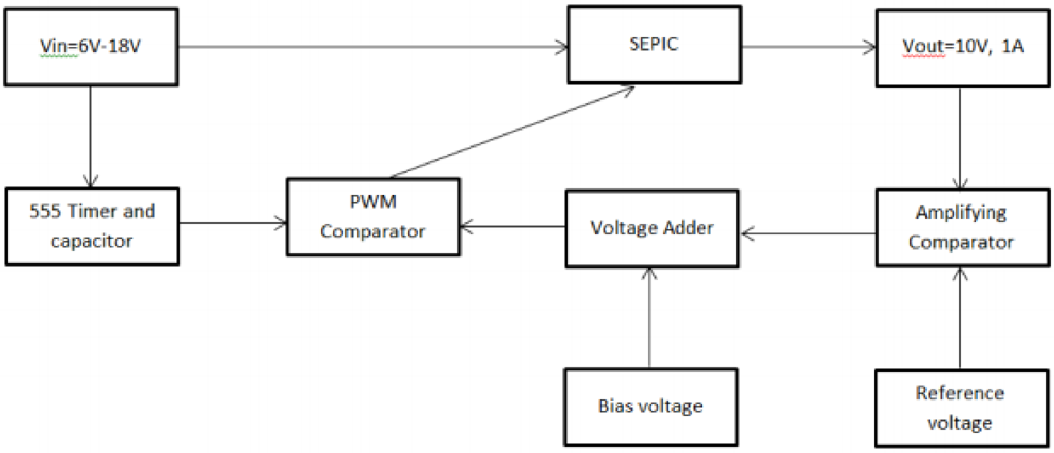

Fig4.4: Flow chart for feedback operation

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CHAPTER 5

SIMULATION RESULTS AND DISCUSSIONS

5.1 CIRCUIT DIAGRAM

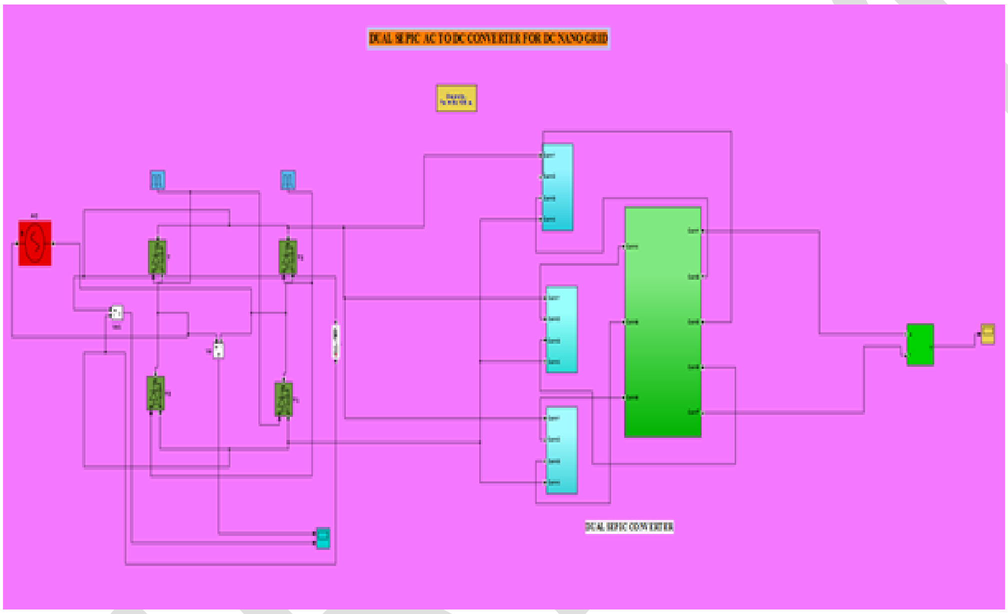

Fig 4.9: circuit diagram for SEPIC AC to DC converter for DC Nano grid

5.2 MATLAB SIMULINK INTRODUCTION

MATLAB, which stands for Matrix Laboratory, is a technical computing environment for high-performance numeric computation and visualization.SIMULINK is a part of MATLAB that can be used to simulate dynamic systems. To facilitate model definition, SIMULINK adds a new class of windows called block diagram windows. In these windows, models are created and edited primarily by mouse-driven commands. Part of mastering

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SIMULINK is to become familiar with manipulating model components within these windows.Log onto one of the PC computers. Click on the Microsoft "Start" button in the bottom corner of your screen and MATLAB will be listed under "Programs". Open MATLAB. To invoke SIMULINK, type SIMULINK at the MATLAB prompt which is indicated by ">>" . A new window titled SIMULINK will open somewhere on the screen.You will have to right click on the Simulink block to make the menu on the right viewable. Once the SIMULINK window block on the right is open, you are ready to build a SIMULINK model.

CHAPTER 6

CONCLUSION

In residential applications, the DC Nano-grid should provide ground line for safety. The grounding configuration determines the different requirements on the AC/DC converters. Three types of the grounding configurations for the DC Nano-grid are summarized. It can be concluded，The united grounding configuration is the most attractive since the DC Nano-grid can be directly connected with the low AC power system using the same ground line, which will strongly address the high efficiency character of the DC Nano-grid. This grounding configuration makes it easy to construct a DC Nano-grid based on the original low voltage AC power system and contributes to the application of the DC Nano-grid. However, suitable AC/DC converters are currently lacking of this grounding configuration. The unidirectional grounding configuration is widely introduced in current DC Nano-grids. It is suitable for construction a new DC Nano-grid alone.

Compared with the united and unidirectional grounding configurations, the flexibility of the virtual isolated grounding configuration is good, but it results in reduced efficiency, more materials, and thereby higher costs. Based on the analysis on the grounding, a dual SEPIC AC/DC converter is proposed for the united grounding configuration based DC Nano-grid. The principle of the proposed converter is illustrated using equivalent circuits. Experiments are in good agreement with the theoretical analysis. The proposed AC/DC converter will help to exploit the application of the DC Nano-grid with three terminal outputs.

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