An Extensive Review on Controlling of Dual-Mode Inverters

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Abstract- A inverter is an electronic circuitry or device that converts direct current (DC) to alternating current (AC). The output voltage, input voltage, and frequency, and overall power handling depend on the design of the specific circuitry or device. Recently, power electronics has evolved and becomes very important in our life. Power electronics is a technology that deals with the conversion and control of electrical power with high-efficiency switching mode electronic devices for a wide range of applications. The variations occurs during power production it is necessary to standardize the inverter operation whether it is grid connected or isolated Since the voltage varies, an inverter with boost converter or another type of inverter called Impedance source inverter(ZSI). This investigation work explores and reviews on Model Predictive Control of Dual-Mode Operations Z-Source Inverter: Islanded and Grid-Connected.

Keyword- Model Predictive Control, Z-Source Inverter, Dual-Mode Operations, Islanded, Grid-Connected.

I. INTRODUCTION

The past decade has witnessed significant development in power conversion technology, thanks to the continuous penetration of power electronics into power generation, transmission and consumption. Power generated from renewable resources is either connected to the grid or to the local loads through inverters. With the performance improvement and cost reduction of the power electronics devices, new topologies of the power converters have become available, reducing the size, saving the energy, and improving the efficiency of the system. The successful operation of the direct control of high performance bidirectional quasi-Z-source inverter with controllable shoot through insertion requires the knowledge of power electronics, converter operation, switching scheme and most important of all control loop design. The focus of this work is on reducing total harmonic distortion and improving voltage gain. The simplification of the available switching scheme and proposed shoot through insertion technique are also considered. A control loop is designed based on a real-time system so that the whole system can meet the design specifications.

Power converters control the flow of power between two systems by changing the character of electrical energy: from direct current to alternating current, from one voltage level to another voltage, or in some other way.

Here, some important way to classify the power converters is described. The aim of this investigation is not to make a rigorous converter classification, neither to make a state of the art, because it is not the purpose of this work. It is only desired to understand some properties of these kind of circuits.

The most common classification of power conversion systems is based on the waveform of the input and output signals, in this case whether they are alternating current (AC) or direct current (DC) (Christiansen, 1996), thus:

- DC to DC converter (Chopper).
- DC to AC converter (Inverter)
- AC to DC converter (Rectifier)
- AC to AC converter (Transformer)

The power inverter is an electronic device that can transform a direct current (DC) into alternating current (AC) at a given voltage and frequency. The inverters are used in photovoltaic off-grid (stand alone) for powering electric remote houses, mountain chalets, mobile homes, boats and are also used in grid-connected photovoltaic systems to enter the current produced by the plant directly into the power grid distribution (solar inverters). The inverters are also used in many other applications, ranging from UPS to speed controllers for electric motors, from power supplies switching to lighting. By the term "inverter" is designed to include a group "rectifier-inverter", supplied with alternating current and used to vary the voltage and the frequency of the alternating current output as a function of the incoming (eg for the supply of particular machinery). The most common inverters used to power the AC loads are of three types: square wave inverter (suitable for resistive loads), modified sine wave inverter (suitable for resistive, capacitive, inductive loads can produce noise) and pure sine wave inverter (suitable for all types of loads because faithfully reproduce a sine wave equal to that of our domestic power supply).

The Z-source inverter is an alternative power conversion topology that can both buck and boost the input voltage using passive components. With its unique structure, Z-source inverter can utilize the shoot through states to boost the output voltage, which improves the inverter reliability greatly, and provides an attractive single stage dc to ac conversion that is able to buck and boost the voltage. The shoot- through duty cycle is used for controlling the dc link voltage boost and hence the output voltage boost of the inverter.

The VSI and CSI have limitations of operation since they can act either as volt- age buck or voltage boost inverter respectively, although extensively utilized in the industry . Thus a boost converter is attached prior to the VSI in case of fuel cells or photovoltaic applications and similarly another DC-DC converter needs to be attached prior to a CSI to generate necessary output voltage. Since it is a tedious process to control two converters (DC-DC converter and the inverter) along with escalation in the costs, Z-source inverters (ZSI) are preferable to them. The ZSI is a single stage inverter with criss-cross of capacitor and inductor to form a X structure between the DC source and the inverter. This helps in operating both in the buck and boost mode depending upon requirement. The special network of two inductor and two capacitors uses shoot through state to achieve buck and boost in the same configuration as per the need. In case of a shoot-through state, the switches in the phase leg are simultaneously shorted. It could be one phase leg at a time, two phase legs or even all of the three.

The configuration of a ZSI is shown in Fig. 1.1.

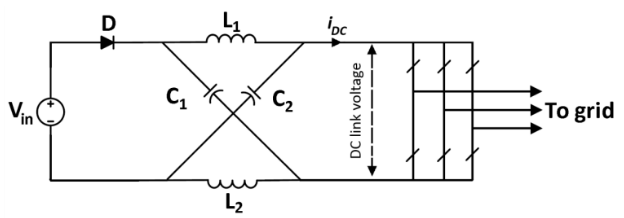

Fig. 1.1 Schematic diagram of a Z-Source Inverter.

II. MODEL PREDICTIVE CONTROL

In conventional electric power grids, large electricity generation units meet the fluctuating demand by adjusting their power output. With the transition towards variable renewable energy sources, e.g. wind and solar energy, the power grid faces new challenges. As renewable generation is highly dependent on weather conditions, its predictability and controllability is limited and plants are smaller and distributed in general. The result is that the ratio between controllable and uncontrollable generation (i.e. renewables) will therefore decrease. This causes a decrease in supply flexibility, which in turn challenges the balance between supply and demand.

Another trend in the power system is the increasing electric load, with transportation shifting towards electric, demand is expected to increase, which especially challenges the maximum power rating of the lower voltage grids

The reliability of a power system has been an important topic of study in recent decades. Power system stability has been recognized as a factor for secure system operation. A secure system provides a constant frequency and constant voltage within limits to customers. To achieve this aim a highly reliable and cost effective long term investment technology is required. Stability limits can define transfer capability. Also in a complex interconnected system, stability has a great impact to increase the reliability and the profits. An example of a large power system formed by interconnection is the South-East Australia power network which connects the five states of Queensland, New South Wales, Victoria, South Australia and Tasmania. Although this interconnection gives the system a complicated dynamic it has advantages such as reduced spinning reserves and a lower electricity price. To achieve these benefits, appropriate control is required to synchronize the machines after a disturbance occurs.

Since 1988 Model Predictive Control (MPC) with over 2000 industrial installation is the most widely implemented advanced process control technology [1]. MPC has gained significant popularity in industry as a tool to optimise system performance while handing the limitation. However, computation competence has limited the application range. The term Model Predictive Control does not delegate a specific control strategy but rather a sufficient range of control methods which make explicit use of a model of the process to obtain the control signal by minimizing an objective function.

Model Predictive Control (MPC) has been shown to be successful in addressing many large scale nonlinear control problems and therefore is worth considering for stabilization of a power system. While MPC is suitable for almost any kind of problem, it displays its main strength when applied to problems with:

- A large number of manipulated and controlled variables
- Constraints imposed on both the manipulated and controlled variables
- Changing control objectives and/or equipment (sensor/actuator) failure
- Time delays
- The strengths of MPC that are relevant to the task of power system stabilization are the explicit

handling of constraints such as the requirement for angles across lines to be kept below 90 degrees.

III. RELATED WORK

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	Model predictive control of dual-mode operations Z-source inverter: Islanded and grid-connected,	S. Sajadian and R. Ahmadi	2017	A model predictive control (MPC) of dual-mode z-source inverters with capability to operate in islanded and grid-connected mode
2	Single-phase dual-mode time-sharing PV string inverter	H. Renaudineau, M. Aguirre and S. Kouro,	2017	a new transformerless PV string inverter is reported
3	Model Predictive-Based Maximum Power Point Tracking for Grid-Tied Photovoltaic Applications Using aZ-Source Inverter,	S. Sajadian and R. Ahmadi,	2016	A model predictive-based maximum power point tracking (MPPT) method for a photovoltaic energy harvesting system based on a single-stage grid-tied Z-source inverter.
4	Power control flexibilities for grid-connected multi-functional photovoltaic inverters,	Y. Yang, F. Blaabjerg, H. Wang and M. G. Simões,	2016	This study explores the integration issues of next-generation high-penetration photovoltaic (PV) systems
5	Islanding Detection in Microgrids Using Harmonic Signatures	J. Merino, P. Mendoza-Araya, G. Venkataramanan and M. Baysal,	2015	A passive islanding detection method based on the change of the 5th harmonic voltage magnitude at the point of common coupling between grid-connected and islanded modes of operation is presented
6	Control strategy for seamless transfer between island and grid-connected operation for a dual-mode photovoltaic inverter	X. Li, H. Zhang and R. Balog	2015	a model predictive control (MPC) for a single phase, grid-connected voltage source inverter (VSI) to support dual-mode operation and seamless transfer between the two has presented
7	Unintentional islanding of distributed generation — Operating experiences from naturally-occurred events	C. Li,	2014	This presents original records of distributed generation unintentional islanding events in three categories.

S. Sajadian and R. Ahmadi, [1] This exploration presents a model predictive control (MPC) of dual-mode z-source inverters with capability to operate in islanded and grid-connected mode. The transition from islanded to grid-connected mode and vice versa can cause significant deviation in voltage and current due to mismatch in phase, frequency, and amplitude of grid voltage and load voltage. This exploration proposes a seamless transition from different modes of operations of z-source inverter using the concept of MPC. The main predictive controller objectives is direct decoupled power control in grid-connected mode and load voltage regulation in case of islanded mode. Direct decoupled active and reactive power control in grid-connected mode enables the proposed power electronics interface to behave as a power conditioning unit for ancillary services such as reactive power compensation. The proposed controller features simplicity, seamless transition between modes of operations, fast dynamic response, and small tracking error in steady state condition of controller objectives. The operation of the proposed system is verified experimentally.

H. Renaudineau, M. Aguirre and S. Kouro, [2] The use of low power PV string inverters, up to a few kW, has been gaining popularity for small scale applications. In this exploration a new transformerless PV string inverter is proposed. This inverter makes use of the inversion stage as an unfolding inverter for high output voltages, and a high switching frequency inverter at low voltages and low current, thus achieving a highly efficient operation. The control of the system is performed by a MPC scheme, which allows the use of a reduced dc-link capacitor. Simulations are presented for a 750VDc 5.6kW 220V_{rms} PV string inverter, showing good results for the proposed inverter and control. Compared with a classical two stage inverter, the proposed PV string inverter presents up to 0.8% higher efficiency for high power operating points, with a maximum simulated efficiency of 96.9%.

D. He, J. Sun and W. Chen, [3] This study proposes an alternative utopia-tracking multiobjective economic model prediction control scheme of constrained non-linear systems with guaranteed asymptotic stability and convergence of average performance. The proposed scheme minimises the distance of its cost function vector to a vector of independently minimised objectives evaluated at ultimate transient operation, i.e. ultimate utopia point. Recursive feasibility and stability of the scheme are established by a closed-loop optimisation dual-mode formulation. Moreover, convergence of the closed-loop average performance is established in the context of multiobjective optimisation. The theoretical results are illustrated by two examples of chemical processes.

Y. Yang, F. Blaabjerg, H. Wang and M. G. Simões, [4] This study explores the integration issues of next-generation high-penetration photovoltaic (PV) systems, where the grid is becoming more decentralised and vulnerable. In that case, the PV systems are expected to be more controllable with higher efficiency and reliability. Provision of ancillary and intelligent services, such as fault ride-through and reactive power compensation, is the key to attain higher utilisation of solar PV energy. Such functionalities for the future PV inverters can contribute to reduced cost of energy, and thus enable more cost-effective PV installations. To implement the advanced features, a flexible power controller is developed in this study, which can be configured in the PV inverter and flexibly change from one to another mode during operation. Based on the single-phase PQ theory, the control strategy offers the possibilities to generate appropriate references for the inner current control loop. The references depend on system conditions and also specific demands from both system operators and prosumers. Besides, this power control strategy can be implemented in commercial PV inverters as a standardised function, and also the operation modes can be achieved online in predesigned PV inverters. Case studies have verified the effectiveness and flexibilities of the proposal to realise the advanced features.

J. Merino, P. Mendoza-Araya, G. Venkataramanan and M. Baysal, [5] In recent years, there has been a growing interest in incorporating microgrids in electrical power networks. This is due to various advantages they present, particularly the possibility of working in either autonomous mode or grid connected, which makes them highly versatile structures for incorporating intermittent generation and energy storage. However, they pose safety issues in being able to support a local island in case of utility disconnection. Thus, in the event of an unintentional island situation, they should be able to detect the loss of mains and disconnect for self-protection and safety reasons. Most of the anti-islanding schemes are implemented within control of single generation devices, such as dc-ac inverters used with solar electric systems being incompatible with the concept of microgrids due to the variety and multiplicity of sources within the microgrid. In this exploration, a passive islanding detection method based on the change of the 5th harmonic voltage magnitude at the point of common coupling between grid-connected and islanded modes of operation is presented. Hardware test results from the application of this approach to a laboratory scale microgrid are shown. The experimental results demonstrate the validity of the proposed method, in meeting the requirements of IEEE 1547 standards.

X. Li, H. Zhang and R. Balog, [6] The dual-mode photovoltaic inverter is capable of operating either in grid-connected mode or island mode, acting as a current source for the ac grid in the former and a voltage source for the load in the latter. Transitioning from one mode to the next is non-trivial and can cause large deviations in voltage, current, and frequency because a mismatch in frequency, phase, and amplitude between the inverter output voltage and the grid voltage. This exploration presents a model predictive control (MPC) for a single phase, grid-connected voltage source inverter (VSI) to support dual-mode operation and seamless transfer between the two. This technique uses decoupled power control in grid-connected mode and voltage control in island mode respectively. Seamless transfer is implemented through synchronization algorithm and smoothly changing weighting factor for the cost function of the MPC. Compared with PI based controller, the MPC controller is simpler to implement since there is only one parameter to tune, the weighting factor. Combined with second order generalized integrator (SOGI), the synchronization algorithm is used to achieve fast phase detection and improved disturbance rejection. The theoretical analysis, simulation and experimental results validate the effectiveness of the proposed control strategy.

C. Li, [7] Summary form only given. This exploration presents original records of distributed generation unintentional islanding events in three categories. The islands were formed by naturally occurred faults without transfer trip initiated to generation facilities. Hydraulic, natural gas and wind generators were involved in the events. The records exemplify important issues in DG anti-islanding planning such as coordination with Under-Frequency (or Under-Voltage) Load-Shedding, reactive power compensation, generation-to-load ratio, reclosing coordination, etc. The events reported in this exploration can serve as first-hand references in applying IEEE Standard 1547 to distributed generation anti-islanding planning and operation.

IV. PROBLEM STATEMENT

Z-Source inverter widely used in many applications that required high controlled. In controlling Z-source inverter current/voltage, there are several ways can be used as conventional PI or PD become a suitable solution. However, the capabilities of these controllers are limited and the performance is not the best possible.

The inverter needs to be controlled. There are many types of controllers. These controllers have solution. However, have the main problem is that large steady state error.

Z-source inverter (ZSI), which is based on Z-source network, can buck and boost the output AC voltage, which is not possible using traditional voltage source or current source inverters. Z-source can have greater output AC voltage than the input, wish is not possible using traditional voltage source or current source inverters.

In order to be able to implement the specified control task of the power scheduler, it is formulated as a MPC optimization problem.

V. CONCLUSION

This investigation briefs the key points and important of ZSI and MPC scheme for various grid applications. A close study of all the relevant topologies reveals that the modifications are motivated by one or more of the following reasons. Since power production through renewable energy sources is a primary need for sustainable development, solar power production with better PQ is a step in that direction. There are some problems in power issues which have been identified over here. The PQ comparison is only with respect to the harmonic content and other PQ aspects are not considered. Only the DC side controller was designed again due to time constraints. The scope of solar power growth in renewable energy sector is huge considering the sustainable power production being regarded the need of the hour. With danger to the environment and consequently to the humanity, focus has shifted to renewable energy for power production all across the globe.

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