Power Quality Expansion for Grid Connected Wind Power System using Permanent Magnet Synchronous Generator and Trans-Z Source Inverter

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Abstract: - This paper presents the expansion of power quality for variable speed Wind Power System (WPS) using Permanent Magnet Synchronous Generator (PMSG) and Trans Z-Source Inverter. The PMSG is having compact collection and dimensions, compare to Induction Generator. Induction Generator needs the grid power, then only start the power production. But without take up the grid power PMSG should produce the power. The impedance-source (Z-source) inverters idea to the Transformer-based Z-Source Inverter (Trans-ZSI) is implemented. The unique Z-Source Inverter (ZSI) employs an impedance network of two inductors and two capacitors coupled in an exceptional preparation to accessing the dc source. In the proposed Fuzzy Logic Controller (FLC) based trans-Z-Source Inverters, the entire impedance networks structure consists of a two transformers and capacitor. While maintaining the major quality of the earlier accessible Z-source network, the new networks demonstrate some unique compensation, such as the enlarged voltage gain, compact voltage stress, privileged inversion capability and very less harmonics content.

Key-words:-Wind Power System (WPS), Permanent Magnet Synchronous Generator (PMSG), Transformer-based Z-Source Inverter (Trans-ZSI) and Fuzzy Logic Controller (FLC).

1 Introduction

In present year's renewable energy source playing major role in our country (India) and world, mainly WPS moreover making a clean environmental i.e. Eco friendly. Now days global warming is a major focussed area, whenever WPS is used avoided the entire global warming processes. Compare to other generation methods, WPS is having huge advantages such as avoid the CO_2 gases, Air Pollution, Water Pollution and Land Pollution etc.

In progress years, a group of occupation has been done in Expansion of power quality using variable generators and power electronic strategy. Unfortunately, most of these systems are not catching power at every wind speed particularly small wind speeds which are short in power but this is can be very common. But clean permanent magnet synchronous generator technology gives high effectiveness power conversion that is mechanical energy into electrical power.

In addition, it allows for exceptional machine plan with very short speed e.g. in gearless wind and hydro occupation and at very high speed for micro-gas turbines, which is of interest for some regenerative or co-generative power translation technologies. An investigation already realized prototypes or in use PM generator systems is presented for that purpose. Compare to other generators that are used in wind turbines the PMSG's have the uppermost compensation because they are steady and protected during normal operation. But do not need an additional AC supply for the excitation circuit (winding). Initially used only for small and medium powers the PMSG's are now used also for higher powers.

In the conventional voltage-source inverter (VSI) and current source inverter (CSI) are used to convert DC to AC and act as a [1], [2] boost or a buck converter. However the DC side cannot be boosted in the predictable inverters. That is, their accessible output voltage range is limited to either greater or smaller than the input voltage. Compare to conventional VSI and CSI [3], [4] in standard Z-Source Inverter (ZSI) voltages boost up level high, because Shoot through state is implemented. The

conventional quasi Z-source inverter (qZSI) was an alternative power conversion concept as it. Mutually the buck and boost operation as well as possible and harmonics [5] also very less. But compared to propose Trans- ZSI is higher voltage gain and compact voltage stress.

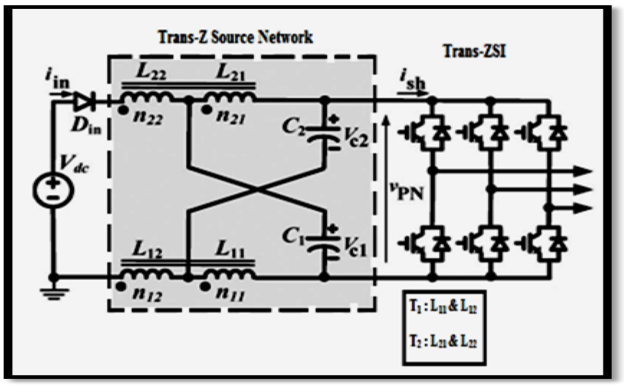

Fig.1 Proposed basic Trans Z-source inverter.

The above fig. 1 shows the proposed Trans-ZSI where the inductors in the original Z-Source Inverter are replaced by the Transformers. It consists of two Transformers (T1 and T2), two Capacitors (C1 and C2), and one Diode (Din). The most important individuality of the proposed Trans ZSI as follows:

1. The fundamental X-shape arrangement is retained.
2. Only two transformers are used, and a very higher boost voltage gain can be obtained by changing the turn ratio of the transformers.
3. While producing a high boost factor, the proposed Trans-ZSI does not utilize any extra diodes, which reduces its range, price, and loss compared to conventional voltage source and current source inverters.
4. It can be extended to the quasi Z-Source Inverter topologies to get better input current shape and place a lower voltage strain on capacitors.

Similar to the established ZSI topology[3],[4], based on the X-shape structure has discontinuous input current, and it need a decoupling capacitor bank at the front end to eliminate current discontinuity and protect the energy source. In addition, it cannot suppress the resonant current at startup, and the resulting voltage and current spike can destroy the devices. The startup resonant current problem can suppress and discontinuous input current problem can eliminate in the proposed Trans- ZSI circuit.

Fuzzy logic controller has speedily become one of the key successful of today's technologies for developing superior control systems. Fuzzy logic controller (FLC) has been extensive to handle the concept of unfair truth, where the truth value may possibly range between completely true and absolutely false.

Additionally, when linguistic variables are used, these degrees could be managed with specific functions. Compare to conventional method [5], [6] and [7] FLC is more quickly tuning of the inverter system. Although variables in mathematics usually take arithmetical values, in fuzzy logic applications, the non-numeric linguistic variables are frequently used to make possible the expression of rules and information.

The linguistic hedges can be linked with assured functions. Fuzzy logic based control technology has been widely and effectively utilized in engineering applications. FLC is a multi-valued logic that allows transitional values to be defined between usual evaluations similar to accurate/fake, sure/negative, high/low and emerged as a tool to deal with undecided, qualitative decision building problems. Fuzzy logic controller is a way to formulate the machines more sharp to motivation in a fuzzy approach like humans, but conventional method not approximating [8]. A FLC model is a logical-mathematical process based on an “IF-THEN” rule system that mimics the human technique if judgment in computational structure.

2 Materials and Method

The below fig. 2 is collected of wind turbines, Permanent Magnet Synchronous Generator, Trans-ZSI and Grid. When the wind is ignition to the blade, the blade should be rotate. The rotating blade is directly coupled with the shaft of the PMSG. So whenever blade is twist, the rotor of the PMSG is also get twist. That time PMSG is produced AC Power, in this AC power directly fed to the diode rectifier. The foremost intention of rectifier is changing the AC power to DC power.

Then subsequent to performing of DC conversion, the DC power is given to the Trans-Z source network. At this point the Trans- ZSI is implemented shoot through state; the DC side should be boosted. Then the boosted DC voltage should be provided the Trans-ZSI inverter, then the inverter converts DC to AC. Using Fuzzy logic controller controlled the inverter and also supplied the power depends on customer loads. Then the quality power from the Trans-ZSI is honestly attached to grid for different customer applications. If a few harmonics nearby in the transmission system to facilitate harmonics can be correct it, by using second order low pass a filter.

The below fig. 3 is Matlab/Simulink diagram of wind power system. The subsystem is denoted in below fig. 4 consist of two step up transformers for progress our power supply. The subsystem is denoted in below fig. 5 consist of six IGBTs based inverter. Due to the square wave from inverter output, it should change into purified sine wave by using this LC filter. Then the quality power is connected to the grid. On other hand same level power generating station is connected to the grid. So we should merge our newly produced quality power supply to that grid through the Trans- ZSI. So by using PMSG and Trans- ZSI, the newly produced power supply has been merged to the grid effectively is shown in a below fig. 3. Remaining power is in spinning reserve. Whenever power demand takes place, at that time utilized.

2.1 Fuzzy Logic Controller

Fuzzy logic is a form of many-valued logic. It deals with understanding that is approximate rather than permanent and truthful. Compared to usual binary sets (somewhere variables may take on true or false values) fuzzy logic variables may possibly restrain a truth value that ranges in degree among 0 and 1. Generally, a fuzzy rule system has four modules; they are Fuzzification, Fuzzy Inference, Rule base and Defuzzification.

Fuzzification way to technique is to be convert crisp data to Membership Functions (MFs). Fuzzy inference, capital combine membership functions with the control rules to derive the fuzzy output. Rule base means under rule base, rules are constructed for outputs. The rules are in "If Then" format and properly the If side is called the conditions and the Then side is called the conclusion. Defuzzification way to use different methods to calculate each coupled output and put them into a table. Pick up the output from the lookup table based on the error current input through an application.

The below fig. 6 basic functional block diagram of Fuzzy Logic Controller. The impression of the fuzzy set is only a conservatory of the concept of a classical (Error) or crisp set. A classical set is a collection of objectives in given range with an intelligent boundary. This classical set can be mapped to a function with two elements 0 or 1. Fuzzy control rule can be measured as the familiarity of an expert in any associated field of applications.

The fuzzy rule is represented by a string of the form IF-THEN, leading to algorithms described output should be taken (plant) in terms of the currently observed information, which includes both input and feedback if a closed loop control system is applied. The IF part is a mainly used to capture the skill by using the expandable conditions, and the THEN part can be utilized to give the conclusion in the linguistic variable.

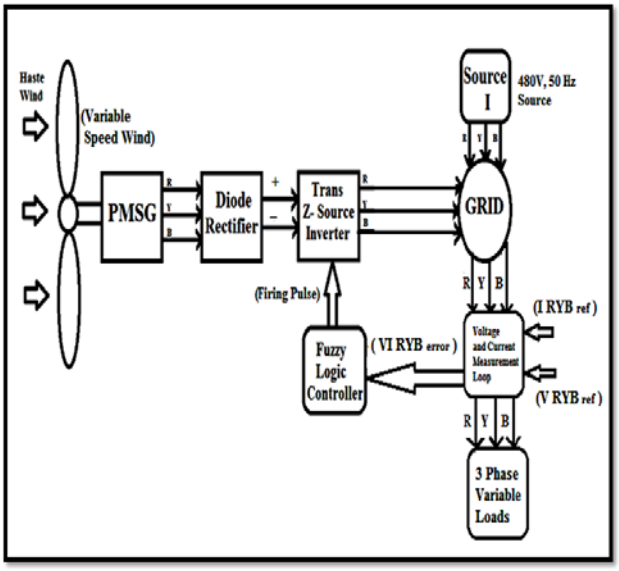

Fig. 2 Block diagram of Proposed Wind Power System.

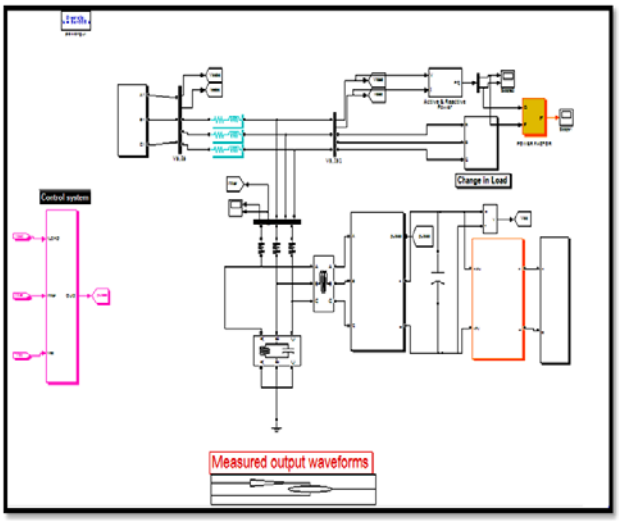

Fig.3 Simulink Diagram of Wind Power System.

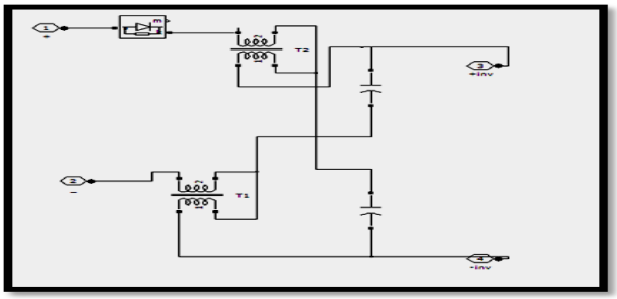

Fig. 4 Simulink Diagram of Trans- Z Source Network.

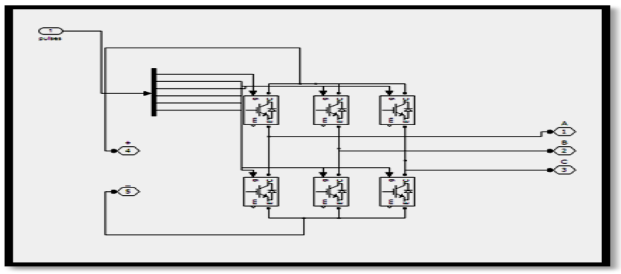

Fig. 5 Simulink Diagram of Trans- Z Source Inverter.

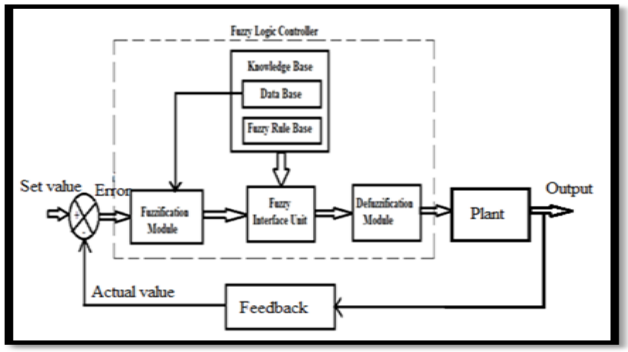

Fig. 6 Basic Architecture of Fuzzy Logic Controller.

TABLE 1
FUZZY 9*9 RULES, MATRIX OF 'STANDARD DESIGN'

Change in Current Error \ Error current (I RYB error)	NB	NM	NS	NVS	Z	PVS	PS	PM	PB
NB	NB	NB	NB	NB	NS	NVS	NVS	NVS	Z
NM	NB	NM	NS	NS	NS	NVS	NVS	Z	PVS
NS	NB	NB	NS	NVS	NVS	NVS	Z	PS	PS
NVS	NB	NS	NVS	NS	NVS	Z	PVS	PS	PS
Z	NS	NS	NVS	NVS	Z	PVS	PVS	PS	PS
PVS	NVS	NS	NS	Z	PVS	PS	PVS	PS	PM
PS	NS	NS	Z	PS	PVS	PVS	PVS	PS	PB
PM	NVS	Z	PVS	PM	PS	PM	PM	PM	PB
PB	Z	PVS	PVS	PM	PS	PM	PB	PB	PB

The fuzzy 9*9 rule-base matrixes for 'standard design' are shown in above Table 1. The values of constants, membership functions and fuzzy sets for input/output variables in this study are selected by trial and error to obtain the most favourable drive presentation. Nine expressions are assigned in above Table 1 NB-negative big, NS- negative small, NM- negative medium, PS- Positive small, PM- positive medium, PB -Positive big, Z - Zero error, NVS- negative very small, PVS- positive very small. Every fuzzy variable is a member of the subsets with a degree of member ship varying between 0 and 1. *IF* the 'current error is NS' *AND* 'change in current error is PS' *THEN* 'change in q-axis reference current is *Z'* (zero error).

The above lookup table 1 is derived based on the membership function of inputs, the output and the fuzzy control rules. A control of triggering pulses is used to fine-tune the output of the lookup table, to obtain different output values. While implementing a FLC technique to a real structure, the lookup table can be stored in a computer's memory, and the fuzzy output can be obtained based on the 3 phase error current and voltage inputs. Based on the fuzzy input firing pulses, inverter should produce the output power. A feedback signal is obtained from the output of the 3 phase grid system. When the system error is becomes to zero, that time the system called as a stability system and also maintain the power quality.

3 Results and Discussion

The exceeding fig.3 Matlab/Simulink is a PMSG generated 550v AC output voltage is showing in the below figure (7). To facilitate time wind turbine speed is 165rpm as shown in under figure (8). PMSG output voltage is provided the diode rectifier; subsequently the diode rectifier converts the 550v AC supply into 520v DC supply output as shown in below figure (9). The DC output voltage is straightforwardly fed to the Trans- ZSI. Earlier convert DC power to AC power, the shoot through state is carried out through Trans-ZSI. As a product the voltage is boosted up to required DC voltage (820v). The result of V_{dc} is publicized in below figure (10). In that case the 820v DC voltage is directly fed to the inverter circuit for function of the inverter; convert the DC supply into AC supply.

That is the 820v DC supply converted into 480v AC supply as shown in below figure (11). Initially the inverter maintained the current 22A, while first load only connected, and then 0.35 second next load will be connected. With the purpose of time, suddenly load will be connected and load value will be changed, so inverter current increased and maintain up to 48A as shown in below figure (12). Before connect the inverter output power to the grid, the harmonics are reduced more and that the harmonics levels are maintained up to 0.07 % in this proposed scheme. It is shown in below figure (13). Using Matlab/ Simulink the inverter current for a choice of power factor is shown in figure (14). But the other generating station i.e. source (1) produced only 480v and 32A current is shown in below figure (15, 16). Here, suppose any load demand is created means, the Trans-ZSI will be compensated. The illustrations of results and controlled technique are mentioned in below comparison Table 2.

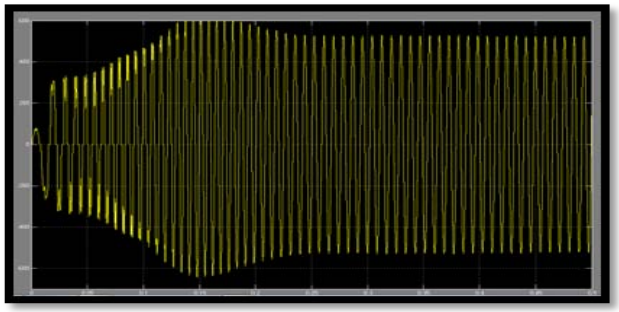

Fig. 7 PMSG Output Voltage (550v).

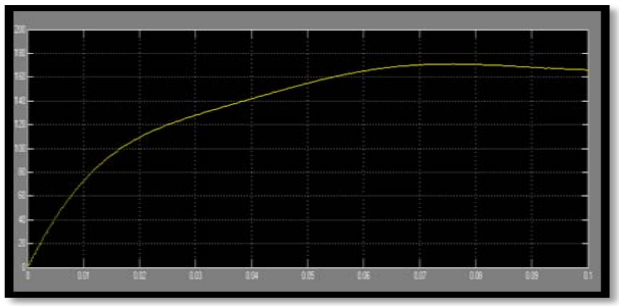

Fig.8 Wind Turbine Speed.

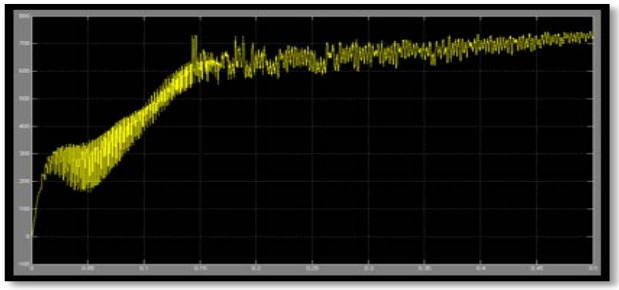

Fig. 9 Diode rectifier Output voltage.

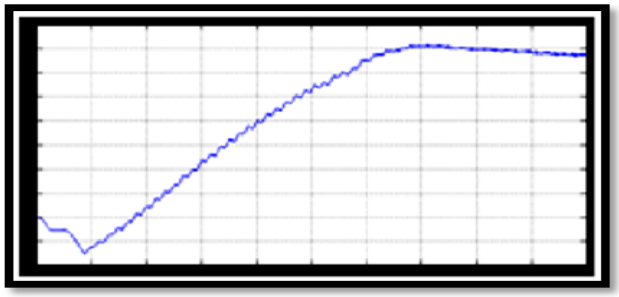

Fig. 10 Trans –ZSI DC Boost Up Voltage (V_{dc}).

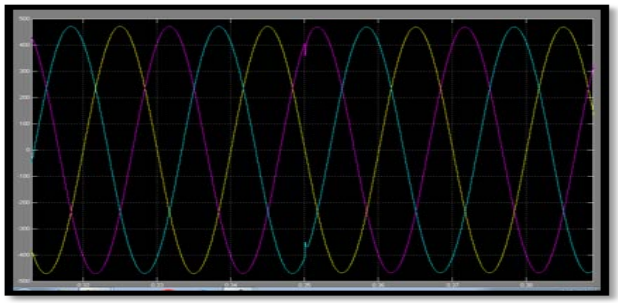

Fig. 11 Trans-ZSI output Voltage 480v (Changeable Loads Condition).

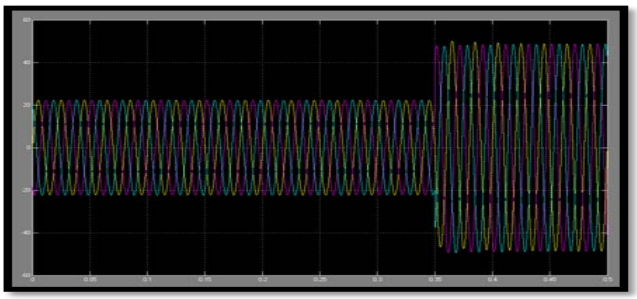

Fig. 12 Trans- ZSI Output Current (Changeable Loads Condition).

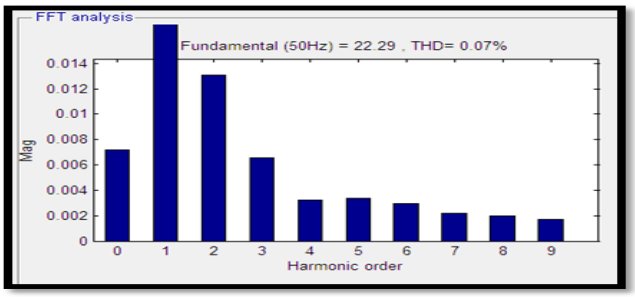

Fig. 13 Total Harmonics Distortion (Changeable Loads Condition).

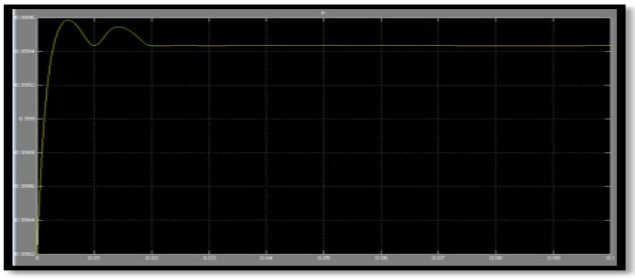

Fig. 14 Power Factor (Changeable Loads Condition).

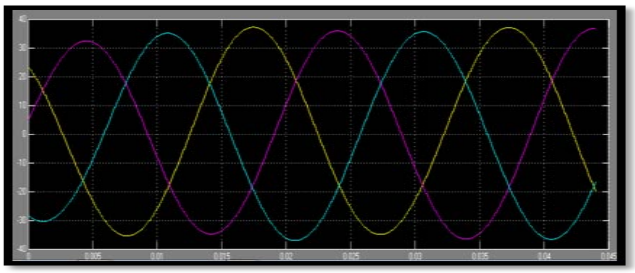

Fig. 15 Source I Voltage (480v).

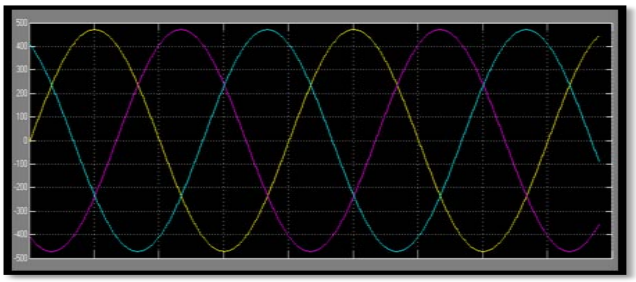

Fig. 16 Source Current (32A).

TABLE 2 RESULT COMPARISONS

S.NO	Parameter	Conventional Method – Reference [1]	Proposed Method
1.	Inverter Type	Quasi Z-Source Inverter	Trans-Z Source Inverter
2.	Inverter Output Voltage	Required Grid Level (Approximately 1000V)	Required Grid Level (Approximately 480V to 1000V)
3.	Inverter Output Current	Required Grid Level (Approximately 200A)	Required Grid Level (Approximately 50A)
4.	Inverter Controlled Technique	Hysteresis Current Control Technique	Fuzzy Logic Controller
5.	Total Harmonics Distortion	0.62%	0.07%
6.	PMSG AC Output Voltage	350V	550V

4 Conclusion

The acquired results designate that the proposed control technique can stabilize the AC bus voltage exclusive of any excessive circuits, on condition that a huge process to increase the better-quality performances of wind energy conversion systems. This paper as accessing an intelligent proposed scheme of the FLC based Trans- ZSI and connecting the output power to the grid element. Evaluate to conservative methods, in this proposed FLC has complementary compensation, such as lucky flexibility, control, superior dynamic and static presentation compared with conventional controller.

The simulation results for PMSG output voltage (550v, AC) and Trans- ZSI output voltage (480v to 1000v, AC or required output voltage) has been verified, and furthermore simulation results demonstrate that the proposed Trans- ZSI has greatest boost potential (850v DC). The proposed FLC based Trans- ZSI is reduced the harmonics level up to 0.07%. Compared to conventional methods and also maintained the unpolluted sinusoidal bus voltage in the grid element.

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