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Power Enhancement Control Strategy for Four Leg Voltage Source Converter Using Inner Control Loop

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Abstract-This work shortly describes the model of the four-leg inverter. The management strategy of the power convertor plays a vital role to confirm reliable and economical operation of the power generation systems. thus for its efficient operation it's here projected a inner control loop controller. The controller works by variable its forgetting issue and former cycle feedback gain. The output of the inverter could be a three part AC voltage that is being fed to the load. The higher than delineate methodology may be additional integrated with the renewable energy resources that manufacture DC output. It will then be regenerate to AC voltage to be fed to the grid. Efforts has been done to investigate the thd level within the output AC voltage undulation. it's finished that if the {value|the worth} of the forgetting issue is reduced there's substantial decrease within the previous cycle feedback gain value of the inner management loop controller then the worth of the thd within the part voltage has been improved. the value of current cycle feedback gain π is kept constant to be a pair of. but additional study shows that any increase within the current cycle feedback gain will improve the thd . however the constant π is finally chosen adequate to a pair of so as to avoid excessive overshoots under transient conditions.

1. Introduction

The four-leg inverter is wide utilised in four-wire micro grids to{supply|to produce} dynamical quality supply for the customers [5].Typically, four-leg inverters ar wont to connect tiny power generation units in parallel with the grid or different sources. they'll not solely feed power into the most grid, however can also perform as power quality conditioners at their grid-connected purpose like Active Power Filters (APFs), Dynamic Voltage Restorers (DVRs) and Unified Power Quality Conditioners (UPQCs) [12–15]. On the opposite hand, it's going to be desirable for them to continue operative in autonomous mode as Voltage supply Inverters (VSIs) once voltages and frequency of the microgrid aren't any longer supported by the most grid. Common samples of autonomous systems operative with four-leg VSIs embody Uninterruptible Power provides (UPSs), single home, large communities, satellite stations, aircrafts and ship propulsion systems [5]. However, four-leg power electronic inverters should be controlled accurately in each grid-connected and autonomous modes so their integration doesn't jeopardize the stability and performance of microgrids.

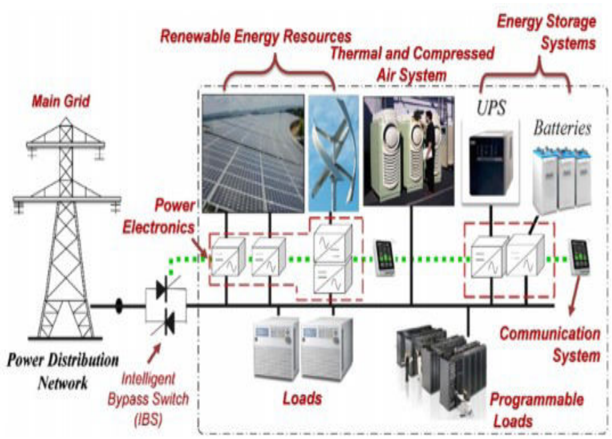

Fig. 1.1. Structure of a typical microgrid

The three-leg inverter with a split dc link capacitor is that the simplest however capacitor voltage equalization may be a problem within the presence of zero sequence current parts. instead one will use a three-leg electrical converter with a D-Y electrical device. The zero sequence current part would be cornered or ‘‘circulating within the D winding’’ and also the feedback loop of the inverter would solely got to make amends for the voltage drops of the positive and negative sequence currents on the output filter of the inverter, within the primary of the electrical device. However, the zero sequence currents can turn out voltage drops within the Y-side of the transformer that the three-leg inverter cannot compensate. For such cases, a four-leg inverter would offer the desired suggests that for voltage equalization. numerous modulation techniques are recommended for change the four-leg inverter. The three-dimensional house vector modulation (3-D SVM) technique was originally projected in [32]. It employs a ab0 transformation and needs advanced calculations for the choice of the change vectors. Carrier-based pulse-width modulation (PWM) is another choice. it's been shown to be such as a 3D SVM however with a neater implementation. owing to that, it had been chosen to be utilized in this work for changing the reference signals from the control loops into gating signals for the four-l inverter.

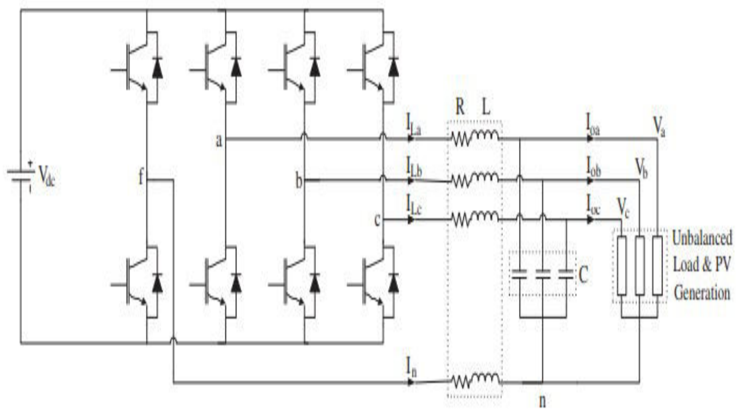

Fig. 1.2. Schematic diagram of a grid-forming inverter with unbalanced loads and source(s)

2. Literature Review

Kim, J.-H. et al.[1] This paper suggests a multi-level four-leg PWM voltage supply inverter (VSI) as a topology for the high power applications wherever a perform is needed to regulate a zero sequence element yet as dq elements. It proposes a carrier-based PWM technique for a multi-level four-leg PWM VSI together with introducing a replacement offset voltage. The projected offset voltage makes it potential for the switch sequence of all the legs to be optimized for the reduction of the harmonic distortion of the output voltage severally of the quantity of electrical converter levels. The feasibleness of the projected PWM technique is verified throughout the spectral analysis, simulation and experimental results.

Liu et al.[2] This paper presents a unified management strategy that permits each islanded and grid-tied operations of three-phase electrical converter in distributed generation, with no would like for switch between 2 corresponding controllers or vital islanding detection. The projected management strategy composes of Associate in Nursing inner electrical device current loop, and a completely unique voltage loop within the synchronous organisation. The electrical converter is regulated as a current supply simply by the inner electrical device current loop in grid-tied operation, and also the voltage controller is mechanically activated to manage the load voltage upon the incidence of islanding. what is more, the waveforms of the grid current within the grid-tied mode and also the load voltage within the islanding mode area unit distorted beneath nonlinear native load with the standard strategy. And this issue is self-addressed by proposing a unified load current feedforward during this paper.

Sinsukthavorn et al.[3] This paper presents the versatile management methodology of inverters as grid side victimisation Associate in Nursing equal control operation that is employed by synchronous generators in typical power systems to supply load sharing and management. The core of those interfacing units is power-electronics grid side, namely, inverters. The electrical converter is that the primary interface that gives not solely their principal interfacing control operation however additionally numerous utility functions.

N.-Y., Wong et al.[4] This paper presents a comparison study between the three-level four-leg authority electrical converter and also the three-level authority electrical converter. aquick and generalized applicable three-dimensional area vector modulation (3DSVM) is projected for dominant a three-level authority electrical converter during a three-phase four-wire system. The zero-sequence element of every vector is taken into account so as to implement the neutral current compensation. each simulation and experimental results area unit given to indicate the effectiveness of the projected 3DSVM management strategy. Comparisons between the 3DSVM and also the three-D physical phenomenon management strategy also are achieved.

3. Objective

The work has been done to obtain following key objectives:

- To design a four leg inverter model which would convert the DC input voltage to three phase AC output voltage that can be fed directly to the AC load.
- To design a suitable controller for the four leg inverter which is would efficiently perform the operation and increase the reliability of the system.
- To design a inner control loop mechanism that would produce pulses to operate the four leg inverter to get the required output.

- To minimize the THD level in the output voltage waveform by properly adjusting the parameters of the Inner control loop.

4. Methodology

4.1 four-leg inverter modeling:

The four-leg inverter topology with associate output inductor capacitor (LC) filter is delineated in Fig. 1.The DC-link is assumed as a continuing voltage supply.The point of the fourth leg is connected to the output capacitor filter and also the load through a neutral inductance Ln so as to cut back the neutral current shift frequency ripple.

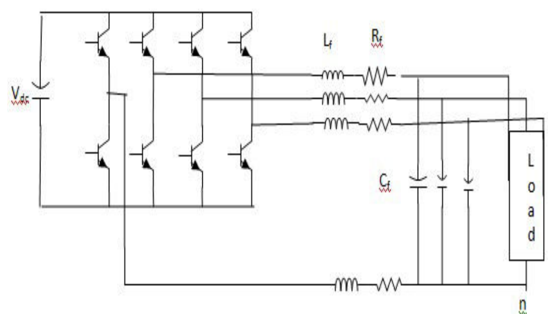

Fig4.1 : Four leg inverter topology

The inverter encompasses two main control loops: the outer loop regulates the output voltage while the inner one maintains the line current within acceptable limits and aims to secure the rejection of the undesired load disturbances**.**

By applying the Kirchhoff's voltage and current laws to the nodes given in Fig. 1, the system behaviour in abc frame can be defined by

$$v_i = v_f + R_f i_f + L_f \frac{di_f}{dt} + \left(R_n i_n + L_n \frac{di_n}{dt} \right)$$

$$C_f \frac{dv_f}{dt} = i_f - i_{L\_abc} \quad \text{(i)}$$

This work outlines a internal current loop PWM modulation scheme for the four-leg DC/AC inverters which has a potential to reduce converter switching loss and the effective switching frequency.

4.2 Internal Loop Controller

An efficient control scheme is proposed for power quality enhancement in a standalone system based on four-leg inverter. The proposed controller is based on Internal loop control mechanism for harmonics attenuation. The load voltage control is achieved by employing both current and voltage control loops to deliver the main inverter input control.

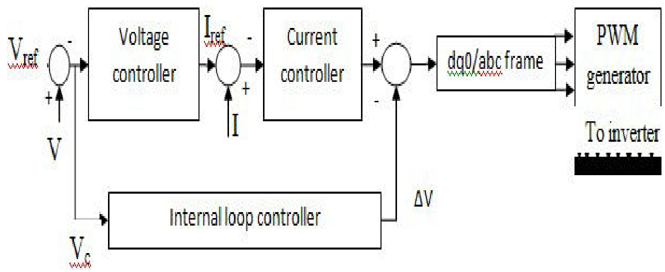

Fig 4.2: Control algorithm to generate pulses

The outer loop regulates the output voltage and provides the inner control loop current references $\boldsymbol{i}_{\text{Ref}} = [i0_{\text{Ref}}, id_{\text{ Ref}}, iq_{\text{Ref}}]^{T}$

When the system is subject to critical disturbances such as the presence of non-linear or unbalanced loads, periodic harmonic components appear in the output voltage waveforms, which may worsen the overall system performances. In this way, and in order to take into account these effects in the control objectives, the proposed solution, based on the Inner Control loop controller, adjusts the inverter input control trajectories as the control task is repeated, with the aim of converging to zero tracking error. In this subject, the controller can produce infinite gains at series of frequencies and achieve a high disturbance rejection with trivial model dependency.

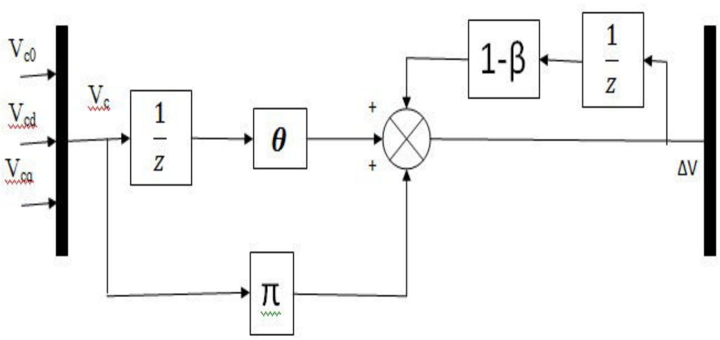

Fig 4.3: The inner loop control

This inequality can be solved as long as $0 < \boldsymbol{\theta} < 2\,L_f$. The forgetting factor β must satisfy the condition $0 < \beta < 1$. Concerning the current cycle feedback gain π, this lastly does not affect the convergence of the learning controller. Its choice is a trade-off between the suited damping performance in steady state and the system behavior at transient conditions.

5. Results

In this work a four leg inverter model has been planned and Inner control Loop controller for generating pulses to the inverter. The inverter then converts the DC voltage into three section output AC voltage. The distinct mode sampling time is kept to be Ts = 1x 10-6. The AC output voltages is then sent to the load. The model will any be integrated with the grid system. so as to beat the poor and unacceptable performance of the traditional solutions throughout unsymmetrical hundreds, an innovative control strategy is anticipated. The planned strategy is predicated on remodeling this and voltage error signals through a inner control loop to beat the deviations and minimize the fluctuations within the AC signal output.

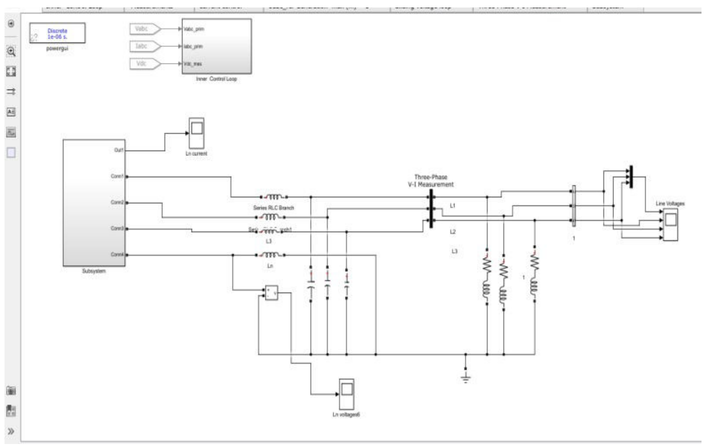

Fig5.1: Modeled four leg inverter feeding three phase static load

The figure 5.2 shows the modeled four leg inverter model. It comprises of eight IGBTS whose internal resistance is kept to be $1x10^{-3}$ ohms and snubber resistance $1x10^{5}$ ohms for each IGBT. The each leg comprises of two IGBTs and there are four legs in this inverter. The input DC voltage is fed to the inverter which is of 700 volts.

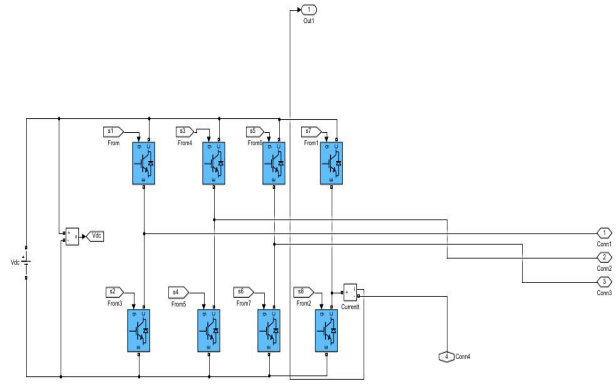

Fig 5.2: Modeled Four leg inverter

5.1 control system:

The output AC voltage is being fed to the first measurement block to convert the voltage from abc/0dq frame. The reference voltage of the voltage regulator is kept to be 100 volts. The difference between the input voltage and reference which is error voltage is fed to the Inner control loop for further calculation. The outputs when fed to the sliding current controller, the generated output from it is added to the output from the Inner control loop. The generated signal is then converted back from 0dq/abc frame. It is then fed to the PWM generator to generate pulses for the inverter.

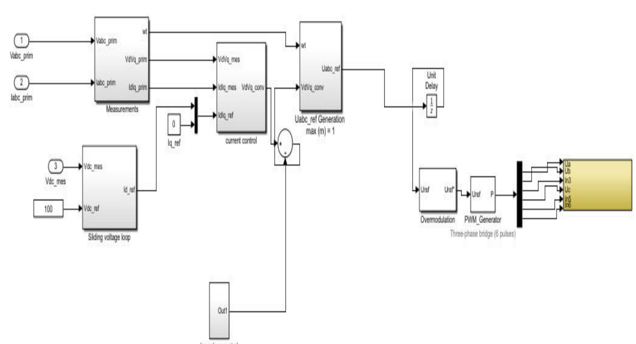

Fig 5.3: Modeled control system to generate pulses

The system is feeding a RL load whose resistance is kept to be 40 ohms and inductance 1mH. The average phase voltage is 500 volts for phase a, 120 volts for phase b and 1500 volts for phase c. While calculating the output active power the output is approximately 6.5 KVA, 7.6KVA and 21.6KVA for three phases respectively. The average phase current is 14 A for phase a, 2.51 A for phase b and 26 A for phase c

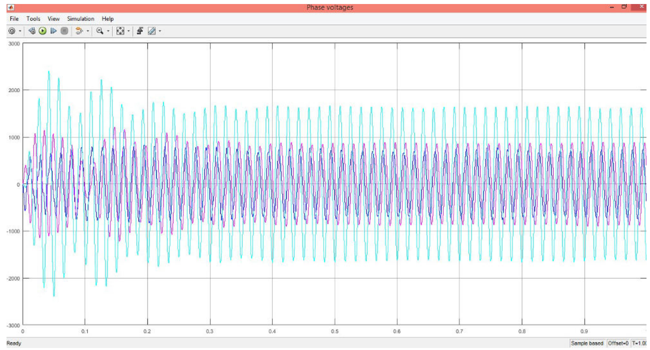

Fig 5.4: Phase voltages

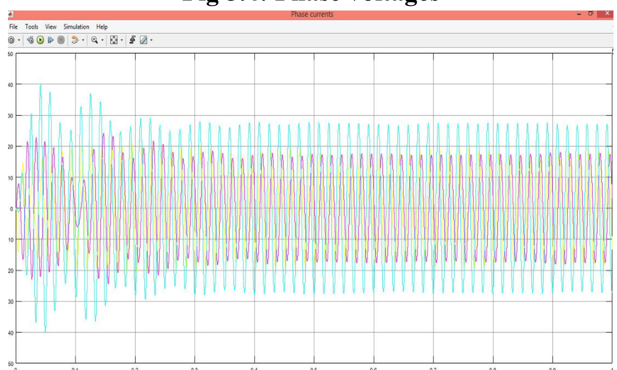

Fig 5.5: Phase currents

Case 1:

In this case the values of the gains is changed. The value of previous cycle feedback gain in the inner control loop is θ=1, also the value of current cycle feed back gain is kept 2, and the value of forgetting factor is kept to be 0.1. The values of THD in the three phases of output AC phase voltage is observed to be as follows. The deviation in values has led to change in the level of THD level:

Table 5.1: THD % for θ=1, β=0.1 and π=2

PHASE VOLTAGE	THD %
Phase a	5.5%
Phase b	1.6%
Phase c	0.5%

Case 2:

The THD distortion calculation has been done by varying the values of the various gains of Inner Control loop controller. The variations effect is being observed in the THD distortion value of the different phase voltages. In second case the value of forgetting factor β is kept to be 0.5 and the previous cycle feedback gain is θ is observed to be 0.002. However the value of current cycle feedback gain π is kept constant to 2. The following observations have been drawn from above parameters.

Table 5.2: THD % for θ=0.002, β=0.5 and π=2

Phase voltage	THD %
Phase a	3.5%
Phase b	0.5%
Phase c	0.3%

This brings us to the conclusion that if the value of the forgetting factor is reduced there is substantial decrease in the previous cycle feedback gain value of the inner control loop controller then the value of the THD% in the phase voltage has been improved. The value of current cycle feedback gain π is kept constant to be 2. However further study shows that any increase in the current cycle feedback gain will also improve the THD% . But the coefficient π is finally chosen equal to 2 in order to avoid excessive overshoots under transient conditions.

6. Conclusion

This paper has projected a inner control loop controller for power quality enhancement in {an exceedingly|in a very} standalone power-supply system supported a four-leg voltage-source inverter with an output LC filter. The projected control theme includes of two principal components. A cascaded voltage and current slippy controllers answerable to deliver the most inverter input control, and an inner control loop whose main purpose is to supply extra support to the principal controller just in case of disturbing hundreds. The provided simulation and experimental results incontestable that the projected approach permits enhancing the facility quality once the system is subject to disturbances like the presence of non-linear and unbalanced hundreds.In summary, the performances of the projected controller will be appropriate for industrial applications wherever the facility could be a concern and also the operative conditions are essential.

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