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Development of a Robust Constant Current Source For a Current Source Inverter

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Abstract:- Current Source Inverter(CSI) has applications in the area of current protection. For CSI fed loads, when connected at a point of common coupling (PCC), the system voltage, may not always be a pure sinusoidal waveform, due to distortions created by other loads at the PCC. This paper presents two simple controllers, namely the comparator type and PI type, to derive and generate a constant current source, as input to be fed to the CSI. Results indicate that these controllers also work effectively even under distorted voltage waveform at the PCC. The controllers are validated for various source conditions and varying load conditions.

Keywords:- current source inverter; point of common coupling; constant current source; power quality; distorted voltage waveform.

I. INTRODUCTION

High power quality and reliability of the power supply are considered to be the most important factors for the supplier and the consumer. These factors are dependent on various parameters like system voltage waveform, current waveform, frequency, nature of load connected to the system and several other issues concerned with power quality. Active filters and controllers when connected to the system, play an important role in improving the power quality of the system. Active filters are classified as current source inverters (CSI) and voltage source inverters(VSI). Both CSI and VSI have various applications, depending on the controllable parameter, which may be voltage or current. The application of a CSI as an active filter, requires a constant current source as its input. This paper proposes two strategies to generate a constant current source.

Harmonics is one of the major issues in power quality. Harmonics may be present either in voltage waveforms or current waveforms, both of which bring down the power quality. These distortions in the waveforms leads to increase in Total Harmonic Distortion. THD forms a good metric to assess the effect of the harmonics present and can be used as a yardstick to decide on the derating required in equipment to account for the harmonics.

The block diagram of a basic network is shown in Fig. 1, representing a system at a point of common coupling(PCC), where different loads are connected. The system voltage is expected to be a purely sinusoidal waveform, but due non-linear characteristics of certain loads connected at PCC, the system voltage waveform may not be purely sinusoidal.

The Current Source Inverter requires a constant current at the DC side and the inverter output voltage is dependent on the load. In this paper, first a simple simulation model is developed to show the basic CSI operation with a

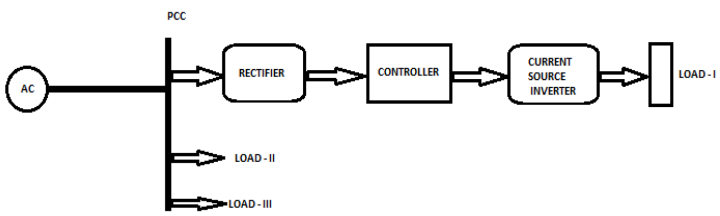


Fig. 1: System Representation At A Point Of Common Coupling

constant current source. For the CSI we need a constant current source at its input, irrespective of the voltage wave shape of the voltage to the rectifier, from which the current source is derived. In this paper, we have tested two types of controllers, to generate a constant current source from a non-sinusoidal ac source. The first method uses a simple comparator type controller. The second type of controller investigated is by using a PI controller. The simulations are conducted and the performance of the controllers validated under both distorted ac source and varying load conditions. The controllers proposed are found to be robust and perform well under all conditions tested.

II. BASIC CSI MODEL

A. CSI Model using Current Source

The basic single phase CSI model is shown in Fig. 2. To develop the CSI model, a constant DC current source, has been assumed as input. The simulations are carried out and the results of the load current and load voltage waveforms are shown in Fig. 3. It can be observed from the waveforms that, the conduction of the IGBT switches used for the inverter are identical to a single phase bridge operation. The amplitude of the output current remains depends on the magnitude of the input DC current..

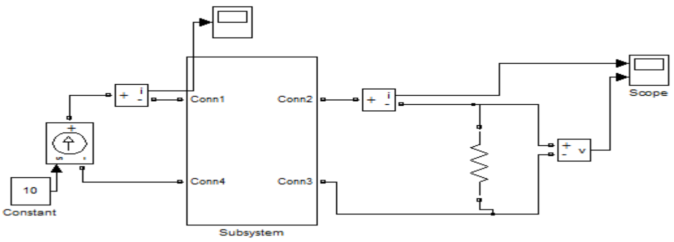


Fig.2: Basic CSI Model

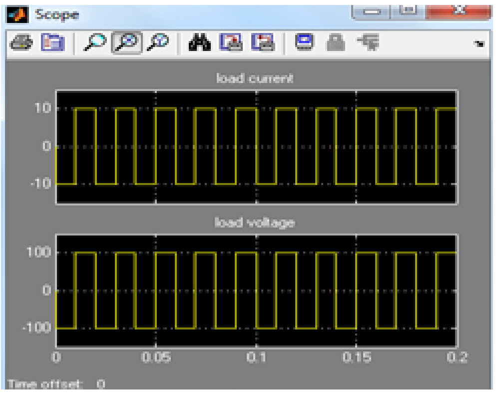


Fig. 3: Load Current / Load Voltage Waveforms

B. CSI Model Without Controller

In a practical situation, the constant current source has to be generated from a voltage source, which may be distorted. Therefore, the constant current source generator must be capable of handling such voltage inputs also. When the system source is sinusoidal, and the load is connected at PCC through a CSI, the CSI requires a constant current source at its input. The conventional type of generating a constant current is by connecting a high inductor in series with the DC link for a CSI, in contrast to a high capacitor, connected in shunt for a VSI. The CSI model operated from a pure sinusoidal voltage source is shown in Fig. 4. The inductor is expected to keep the current a constant, and this is fed as input to the CSI. The source voltage, source current, dc link current and the load current waveforms are shown in Fig. 5. It can be observed that the dc link current is a constant.

However, the CSI needs to be supplied with a constant dc current, even when it is directly connected through a distorted ac source. It is still possible to generate a constant dc link current by connecting a high series inductor in the dc link. This dc link current magnitude, varies with the load. The simulated results for a particular load, when CSI is fed from a distorted AC source are shown in Fig. 6. It can be observed from the waveforms, shown in the Fig. 5 and 6, that, under both the situations, of a sinusoidal AC source or a distorted source, at a given load condition, the DC link current can be maintained constant due to a high inductor, connected in series.

The inductor connected in series has its own limitations. The variation in the magnitude of the dc link current due to the changes in the load is shown in Table 1. It can be observed that there is a wide variation in the dc link current with varying load.

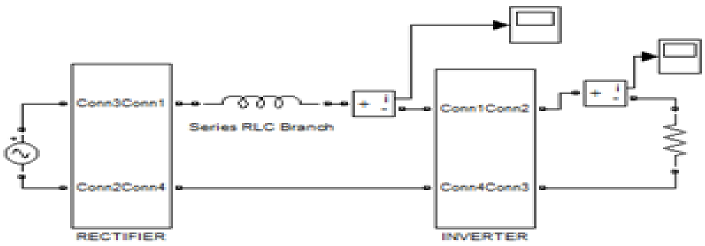
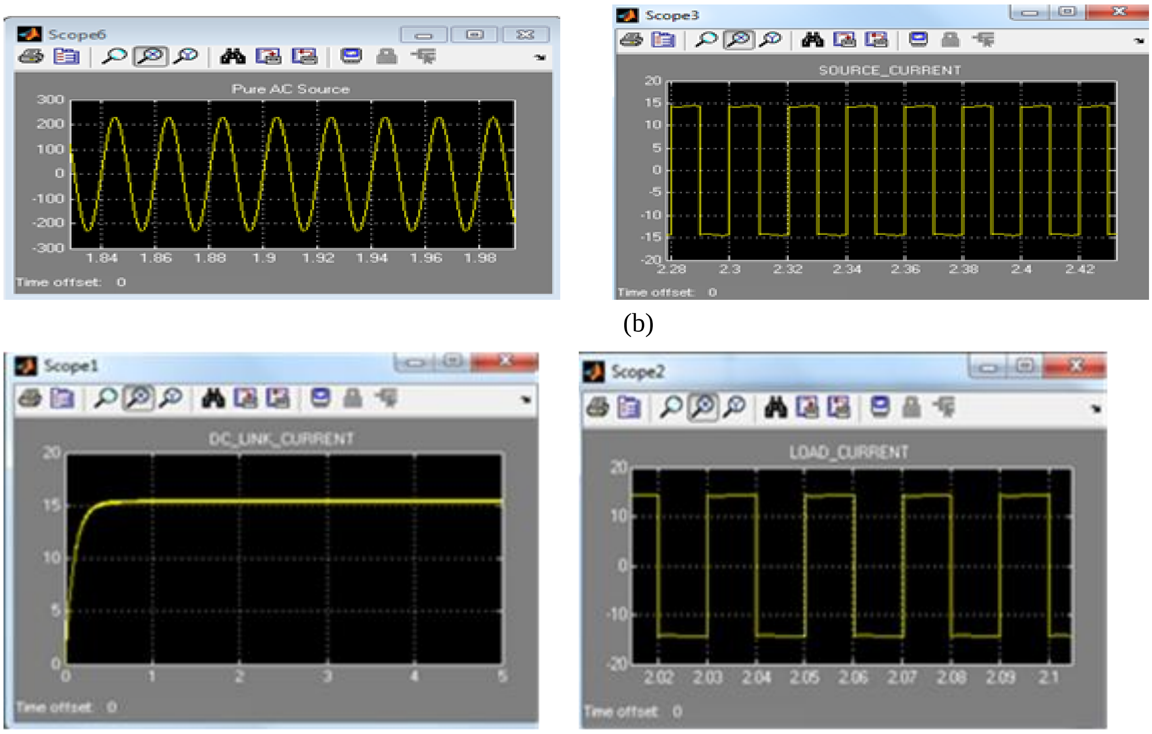


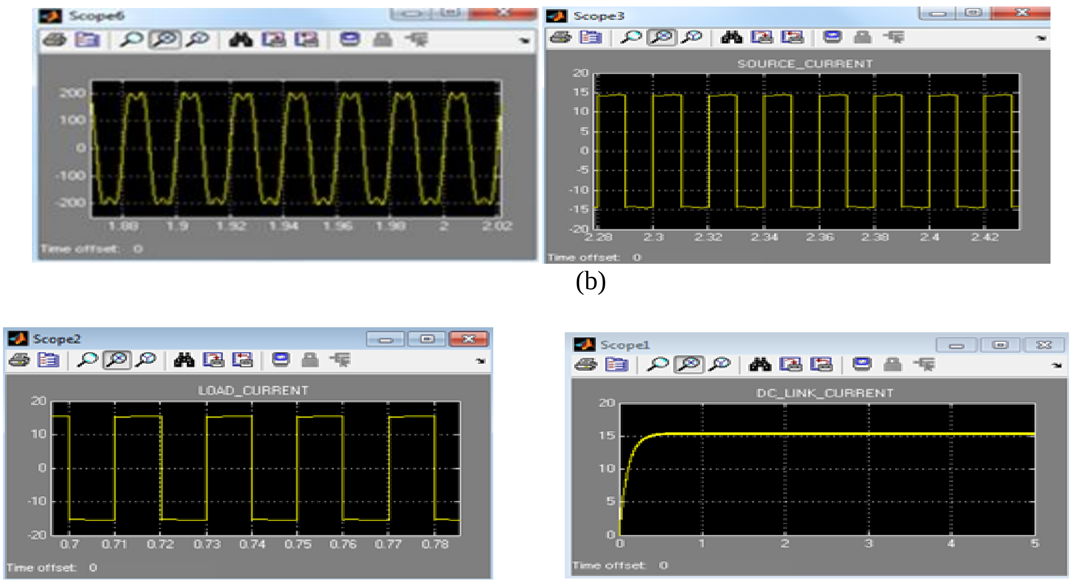
Fig. 4: CSI Simulated Model From A Pure AC Source



(a) (b)

(c) (d)

Fig. 5: (a) source voltage waveform (b) source current waveform (c) dc link current (d) load current waveform



(a) (b)

(c) (d)

Figure 6. (a) distorted voltage source (b) source current (c)) dc link current (d) inverter output current

Table 1: V_{DC} and I_{DC} without controller

R_L Ω	PURE AC SOURCE		DISTORTED AC SOURCE	
	I_{DC}	V_{DC}	I_{DC}	V_{DC}
5	28.62	145.6	30.77	156.3
10	14.32	145.6	15.39	156.3
15	9.549	145.6	10.27	156.3
20	7.163	145.6	7.701	156.3

III. CSI WITH CONTROLLER

A. Comparator Type Controller

A simple comparator type controller is added to obtain constant current under varying load conditions The CSI - source current and hence the load current amplitude remains constant even under variable load conditions while CSI output voltage varies. This is necessary when it is required to drive a constant current load. Fig. 7 shows the basic block diagram representation of a complete AC – DC – AC converter with comparator type controller. Fig. 8 shows the block diagram representation of a comparator type controller along with the gate pulses generated for the switches connected to rectifier bridge. In the comparator, the rectifier output current is compared with a reference constant current to generate the error signal. This error signal is compared with a carrier waveform to generate the gate pulses. Here, the pulse width is controlled by the error signal. With this simple comparator type controller, DC link current is held constant for a range of varying load conditions.

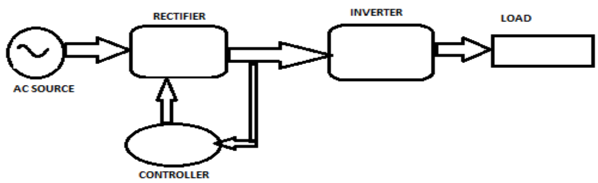


Fig.7: Block Diagram Representation Of A Complete Ac – Dc – Ac Converter

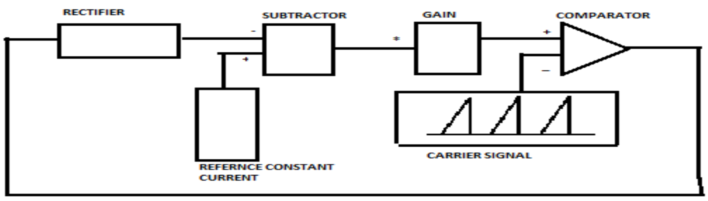
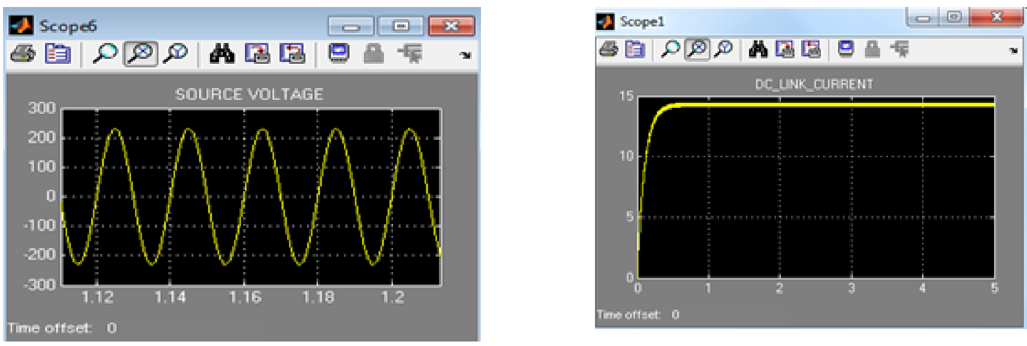


Figure 8. Comparator To Generate Gate Pulses

The Simulation is carried out using the above concept and the results are verified for generation of constant current when input AC source is a pure sinusoidal waveform and by varying the load at the CSI output. The waveforms for one particular load and reference current for the controller, kept 15 amperes, is shown in Fig. 9. The simulation is repeated, when the input AC source is a distorted waveform. The waveforms for the second case is shown in Fig. 10. From the waveforms, it can be observed that,with the source voltage being either sinusoidal or non-sinusoidal, the simple comparator type controller can generate a constant current source.



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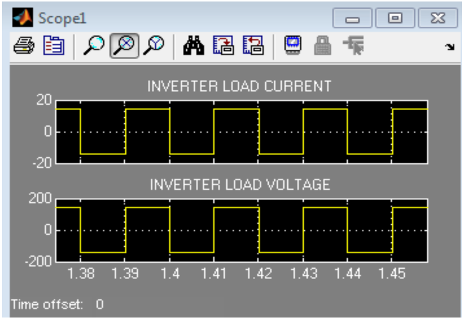

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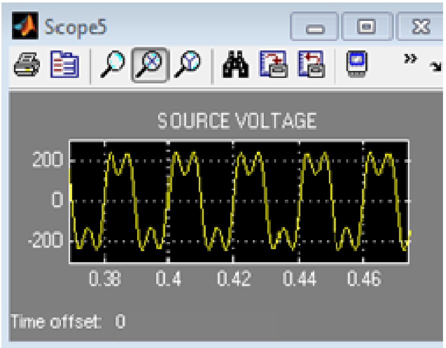
Fig. 9: Waveforms From A Pure Ac Source with comparator



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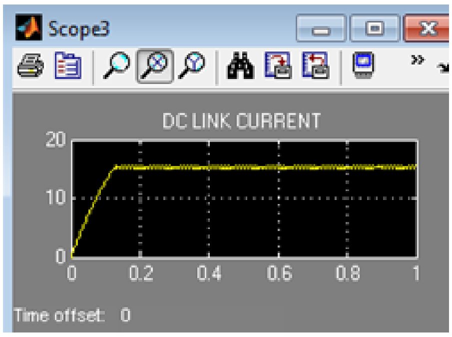

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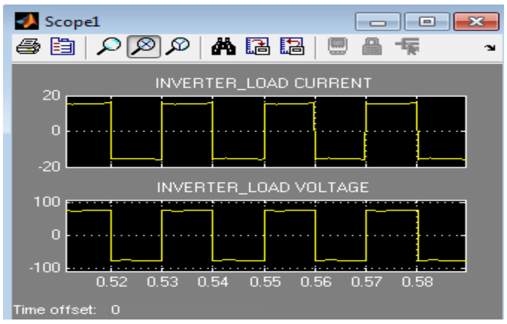

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Figure 10. Waveforms From A Distorted Ac Source

Table 2. [With Comparator Type Controller]

R_L Ω	**PURE AC SOURCE**		**DISTORTED AC SOURCE**	
	I_{DC}	**V_{DC}**	**I_{DC}**	**V_{DC}**
5	5.592	31.14	5.545	30.97
10	5.539	58.13	5.475	57.58
15	5.45	84.13	5.4	83.43
20	5.349	109	5.321	108.5

From Table 2, it can be observed that for varying load conditions, the source current for the CSI is maintained constant and the voltage is dependent on the load variations. In this case study, the controller reference current was chosen as 5 amperes. Hence the controller maintained the DC link current at 5 amperes.

B. **PI CONTROLLER**

A simple PI controller has been tried to generate a constant DC link current. A Simulink model, using PI controller is shown in Fig. 11. The simulation is carried out for input AC being a pure sine waveform and under varying load. It was observed that, the controller generates a constant current, as an input source to the CSI. The simulated waveforms for the input being pure sinusoidal AC source are shown in Fig. 12. The analysis is also done, when AC source is a distorted waveform. The waveforms for the second case is shown in Fig. 13.

From the waveforms, shown in Fig. 12 and Fig. 13, it is observed that, even when the source contains harmonic distortions, the controller is able to generate a constant current magnitude, at the output of AC – DC converter.

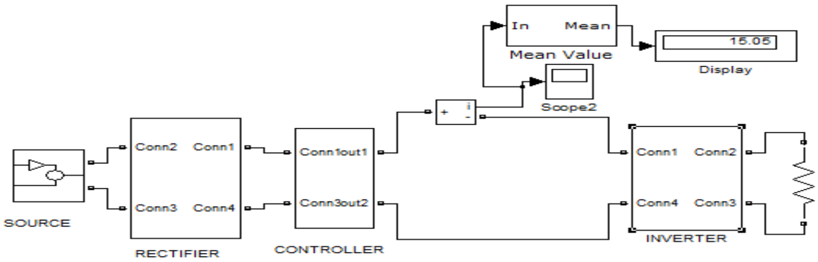
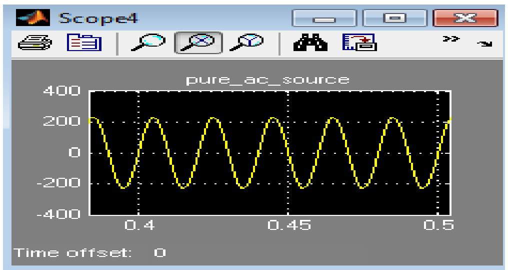


Fig. 11: Simulink Model Using PI Controller



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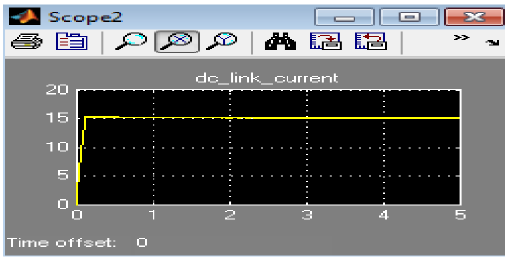

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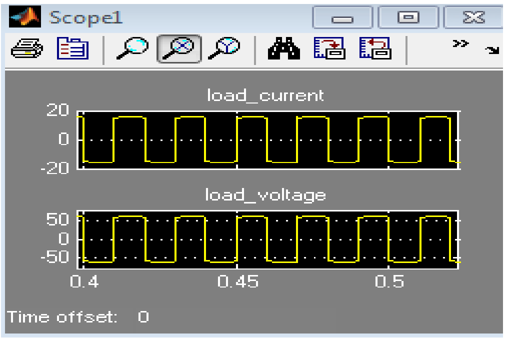

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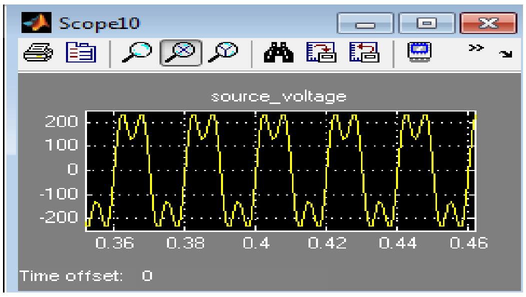
Fig.12: Waveforms From A Pure Ac Source with PI controller

From the waveforms, shown in Fig. 12 and Fig. 13, it is observed that, even when the source contains harmonic distortions, the controller is able to generate a constant current magnitude, at the output of AC – DC converter. The controller is tested for a widely varying range of load and the results are shown in Table 3. The range of load depends upon the reference current defined for the controller. For a constant current source of 5 amperes, the simulation is carried out, using PI controller, and the readings are tabulated in Table 3. These results shown in Table 2 and 3 can be compared with the results that are shown, without a comparator.



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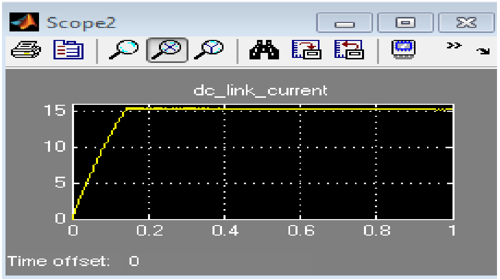

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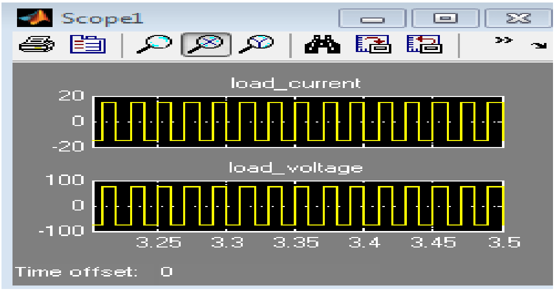

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Fig.13: Waveforms From A Distorted Source with PI controller

Table 3. [With PI Controller]

R_L Ω	PURE AC SOURCE		DISTORTED AC SOURCE	
	I_{DC}	V_{DC}	I_{DC}	V_{DC}
5	5.024	28.31	5.011	28.35
10	5.024	53.07	5.011	53.01
15	5.011	77.66	5.011	77.81
20	4.984	101.8	5.015	102.5

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Recommended font sizes are shown in Table 1.

IV. CONCLUSION

In practice , for current source inverter-fed loads, the basic requirement is constant current source, which is not readily available and needs to be generated. In this paper, two controller, namely a comparator type and a PI type, have been investigated. Both the controllers exhibit superior performance as compared to the case when the controller is not used. Through appropriate design, this concept can be extended for higher power ratings. Further, the Total Harmonic Distortion of the inverter load current waveform, can be held within limits by using appropriate switching techniques for CSI, in addition to the controllers used above.

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