

PI Based Synchronization Techniques for Parallel Inverters Supplying the Single Motor Load

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Abstract— Parallel connection of inverters or converters is one useful method for solving the high power requirements. The parallel connection of inverters reduces the current stress on inverter switches and makes the way for continuous supply to the load. Though any one of the inverter supplying the load gets faulted, the other inverter connected would supply the load. But the problem in this kind of set up is that it needs synchronization techniques for parallel operation or else the inverters will operate in unsynchronized manner and the supply would be in distorted form for the motor load leading to overheating of the load. This paper proposes software drive control technique for the parallel operation of inverters in synchronized condition. The software technique is implemented and results are analysed in the MATLAB environment.

Keywords—Parallel Inverters; Synchronization; Phase difference

I. INTRODUCTION

The power conversion system with large capacity, high reliability, and standard structure, which is realized by multiple power modules operating in parallel mode, is one of the developing trends in modern power electronics technology. Parallel set operation of power modules offers way to increase the power handling capacity of the inverter sets. The total load power is shared among the parallel power modules, the current stress of the power switches of each module is quite small, and the high reliability of the parallel system is obtained. The N+1 redundant parallel operation

manner is the optimal scheme for the large power capacity system with high reliability because the fault tolerant power is obtained at low expense.

The parallel operation of power converters is the most helpful technique in the industries running critical load. This technique helps to run the load continuously without stopping it and buys time to get replace faulted inverter and put it back on track for supply. Besides these advantages the parallel operation of inverters have synchronization problem. It occurs mainly due to the difference in switching time of the inverters. It can be avoided by providing similar pulses for both the inverters. The inverters should be operated at synchronized condition for proper current sharing and eliminate circulating current. If they are not synchronized then there would be phase difference between the outputs of two inverters leading to flow of circulating current in the circuit and the motor load would be affected. So the synchronization method is essential for parallel operation. There are several synchronization techniques available for the parallel operation of inverters. The hardware control techniques includes current control scheme[1], controlling the circulating current using balancing reactors[3], decoupled control[2],[4].

In this study software drive control technique is discussed and analysed. As the Pulse Width Modulation(PWM) inverters are useful and easy to control the output voltage, it is used as a drive for supplying the three phase ac induction motor load in this study. The software drive control technique done by

controlling the phase angles of input reference waveforms of parallel inverters using three techniques are simulated in the MATLAB environment and the performance of the motor is observed.

II. PARALLEL OPERATION OF INVERTERS

The two three phase PWM inverters are connected in parallel to perform the parallel operation of inverters. The source for the inverters can be separate or same DC source can be used. In this study the parallel inverters are fed from a common rectified DC source. The output from the parallel inverters is given to a single three phase induction motor load. Since the two inverters are connected in parallel the current for the load is equally shared by the two inverters. This makes the reduction in current stress on inverter switches. Fig.2 shows the parallel connection of inverters which is supplying a single three phase induction motor load. A three phase AC source of 440V, 50Hz supplying induction motor load of 4kW, 400V, 1430 rpm is considered for the analysis. Fig.1 shows the parameters of the components considered for simulation.

AC Source	440V(rms), 50Hz
Rectifier	Input 440V(rms) Output 600V(avg)
Parallel Inverters	Input 600V Output voltage 400V(rms) Output current 10A(rms)
Motor load	Rated power 4kW Rated voltage 400V Rated speed 1430rpm

Fig.1 Parameters of the parallel inverter system

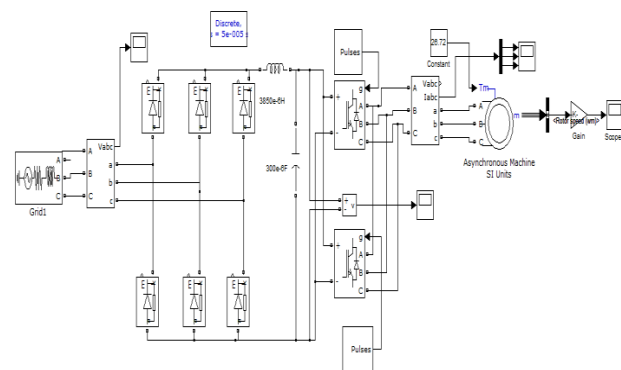


Fig.2 Parallel inverters configuration

In the Fig.2, the two inverters are in synchronized condition as pulses for two inverters are similar and are given directly from the pulse generators. Therefore there would be no phase difference between the inverters voltage and current.

III. PROPOSED METHODOLOGY

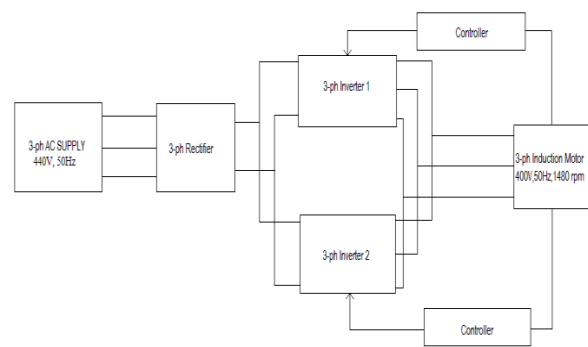


Fig.6 Block diagram of parallel inverters with controller

As Fig.6 shows, the two three phase inverters are connected parallel and given supply to the induction motor load. The load shared by the two inverters. The inverters are getting rectified input from the three phase ac supply. As it said above when any one inverter gets faulted, the supply to the load can be maintained by other inverter. This is the advantage of parallel connection of inverters. The inverters are getting pulses from the feedback from motor load. The pulses are needed to be in the form of synchronizing the two inverters and preventing the circulating current. The synchronization of pulses for parallel inverters are done using PI controller

A. Phase difference control using PI controller

The phase difference between the inverter references is found and it is subtracted from the second inverter reference to obtain the synchronization. This method uses the Proportional-Integral (PI) controller for maintaining the error angle in first two quadrants. Fig.7 shows the phase difference control block with PI controller.

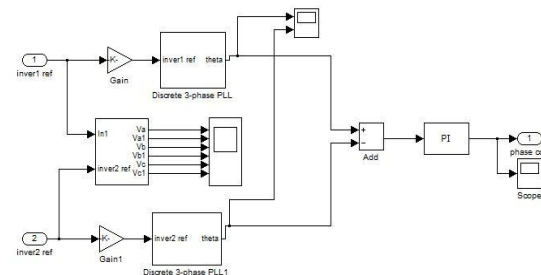


Fig.7 Phase difference control block with PI controller

IV. SIMULATION AND RESULTS

A. Open loop parallel inverters

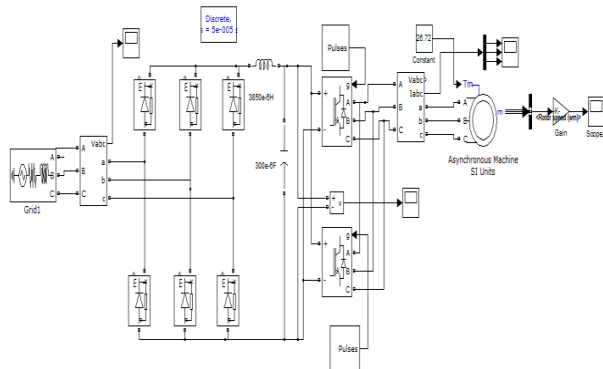


Fig.8 Parallel Inverters supplying a single motor load in open loop

Fig.8 shows the simulation of parallel inverters supplying a single motor load with pulses directly given to the inverters from pulse generators. The phase difference between the pulses is zero and hence both inverters would be operated in synchronized condition. The motor load considered is a three phase induction motor with the rated parameters of 4-pole, 400V, 50Hz, 1430 rpm and full load torque of 26.72 N.m. The supply from the parallel inverters is given to the motor load and speed of the motor is verified. Fig.9-12 shows the comparison of simulation results of parallel inverters in open loop condition. Fig.9 shows the current shared by the two inverters without having any phase difference between them. Fig.10 shows the current waveform of parallel inverters. From Fig.10 it is observed that the maximum current of 15 Amps is achieved from the parallel inverters to supply the motor load. From Fig.11 it is observed that the maximum voltage of 600V is achieved from the parallel inverters to supply the motor load. Fig.12 shows the speed waveform of motor. It shows that the motor is running linearly without any distortion.

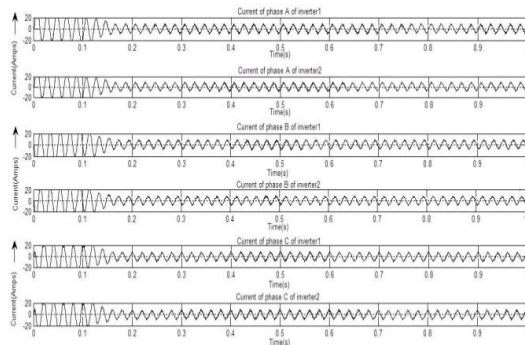


Fig.9 Current waveforms of both the inverters

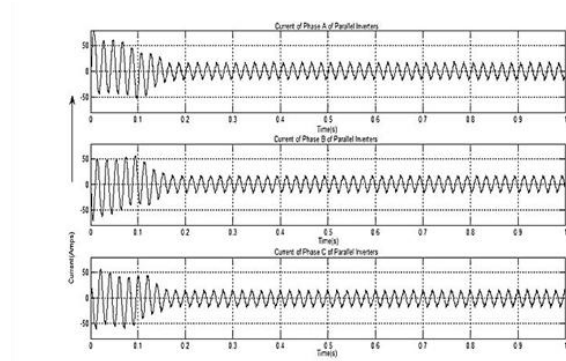


Fig.10 Three phase current waveform of parallel inverters in open loop

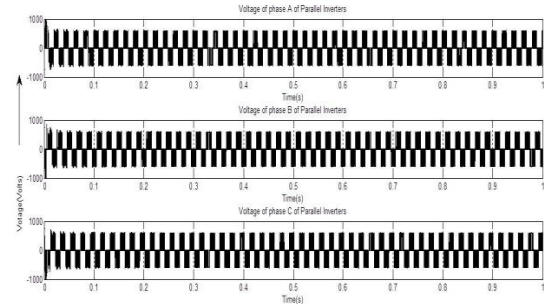


Fig.11 Three phase voltage waveform of parallel inverters in open loop

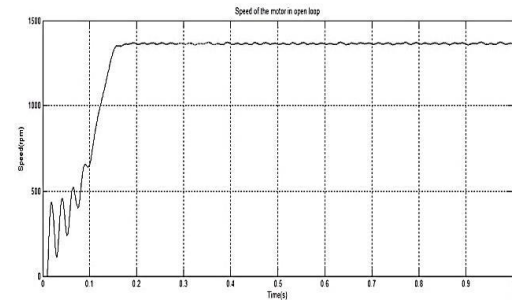


Fig.12 Speed waveform of the motor supplied from parallel inverters in open loop

B. Phase angle control with PI Controller Block

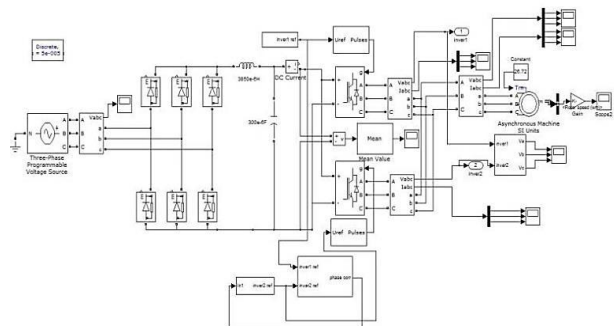


Fig.13 Circuit of parallel inverters using phase difference control with PI controller

Fig.13 shows the parallel inverters controlled using phase angle difference control and PI controller. The references for two inverters are generated separately and phase difference between the two references is found. The phase angle difference

between the two inverters is nullified using PI block and maintained in positive value. The output voltage and current obtained using this control are similar to that in open loop condition.

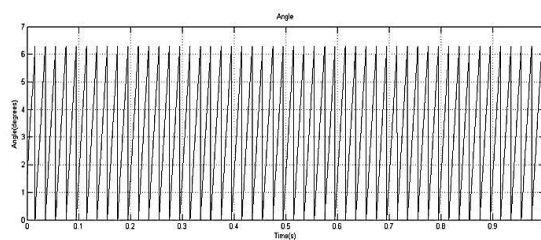


Fig.14 Phase angle waveform of first inverter

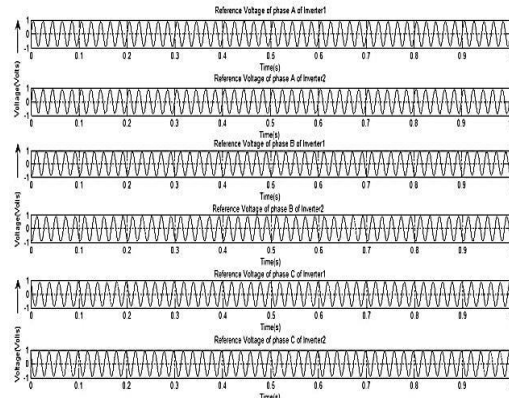


Fig.15 Synchronized reference voltage waveform of parallel inverters

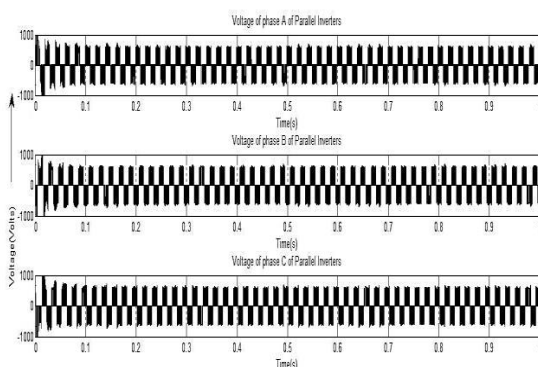


Fig.16 Voltage waveform of parallel inverters using phase angle control with PI controller

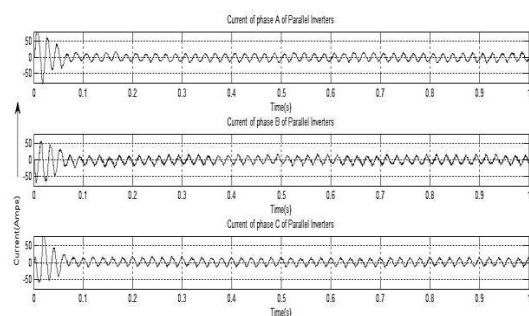


Fig.17 Current waveform of parallel inverters using phase angle control with PI controller

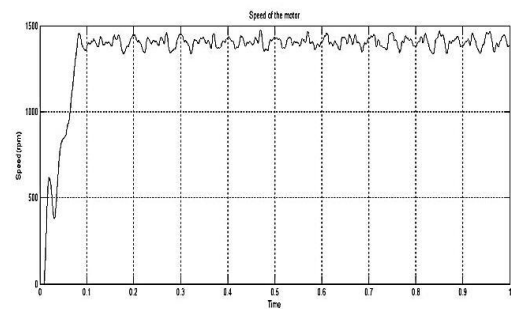


Fig.18 Speed waveform of the motor supplied from parallel inverters using phase angle control with PI controller

Fig.14 shows the mechanical degrees of phase angle of first inverter reference which is given to the second inverter reference as input. Fig.15 shows the synchronized voltage reference waveform of both the inverters. It shows that the reference waveforms are in phase and hence the inverters are synchronized. Fig.16 and Fig.17 indicates the voltage and current waveforms of parallel inverters using PI controller which are similar to that of achieved in open loop. Fig.18 shows the speed waveform of the motor which indicates that motor is running linearly using the phase angle control using PI controller block for parallel inverters.

V. CONCLUSION

This paper has proposed the software drive control technique for the parallel operation of inverters using PI controller block. The proposed software drive control technique does not need any additional hardware set up for giving pulses to the parallel inverter. The control technique stated in this paper requires programming of drive controller. The phase angle control with PI controller gives required output but needs fine tuning for smooth response. Thus the voltages, currents and speed of the motor are obtained and the waveforms are analyzed in the MATLAB environment. The parallel inverters are exactly synchronized using the PI based phase angle synchronization technique.

As a future work, filter at the output of parallel inverter would be designed to minimize the ripples in the voltage and current, and to attain the steady state quickly.

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