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# Performance Evaluation of Dc Motor with Power Factor Correction At Input Stage of Three Phase Diode Rectifier

KEYWORDS: Bidirectional switch, MOSFET, three phase diode rectifier, DC drives.

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**ABSTRACT** *This work describes a method in improving the input current total harmonic distortion as well as power factor of a three-phase diode rectifier circuit. In this method, three bidirectional switches comprising MOSFET and four diodes are used across the three-phase supply and load. In a three-phase rectifier only two diodes conduct at any given time. As a result, the current in the third phase is zero. But in this method, the bidirectional switch corresponding to the third phase is turned ON. Once the input voltage crosses zero-voltage axes, the corresponding switch will be triggered. Each bidirectional switch receives a pulse of 30° in width following the zero-crossing point of corresponding phase voltage. The closing of bidirectional switches provides an alternate path for the input current to flow. The performance of DC motor is evaluated with this method.*

## 1. Introduction

Traditionally, three-phase ac-to-dc high power conversion is performed by diode or phase-controlled rectifiers. Due to the commutation of these structures at the zero crossing of the current, they are also called "line-commutated" rectifiers. These rectifiers are robust and present low cost, but draw non sinusoidal currents or reactive power from the source, which deteriorate the power quality. To compensate for the harmonic distortion generated by the standard diode rectifiers, passive linear filters or power factor correction structures can be employed [1–3]. The multi pulse three-phase rectifiers achieve harmonic cancellation by introducing phase shift by means of special three-phase transformers [4-5]. Moreover, the simplicity and reliability ability of the diode rectifiers are preserved. However, they are heavy, bulky, and expensive.

Three-phase pulse width modulation (PWM) rectifiers are widely employed in low- and medium-power drive applications where the requirements established by international standards should be satisfied [6–9]. These structures are the most promising rectifiers from a power quality viewpoint [10-12] since they can present low harmonic distortion and unity power factor.

Recent trends in high-power rectifiers have introduced a new class of three-phase rectifiers, the hybrid rectifiers [13–15]. The term "hybrid rectifier" denotes the series and/or parallel connection of a line-commutated rectifier and a self-commutated converter. The line-commutated rectifier operates at low frequency and has a higher output power rating. The active rectifier is designed to operate with a small power rating and at a high switching frequency [16].

The sub harmonic pulse width modulation strategy reduces the THD and switching frequency optimal pulse width modulation strategies enhances the fundamental output voltage. The multilevel inverter improves output voltage, reduces output total harmonic distortion and voltage stress on semiconductors switches. These schemes are confirmed by simulation results and experimental results [17].

THD analysis and distortion factor have been estimated for different modulation indices. From the analysis we can say that the THD for PS technique for MI =1 is less when compared with APOD, PD, POD and Hybrid control techniques. In that PS technique also, bipolar mode of operation has given less THD values compared to unipolar [18].

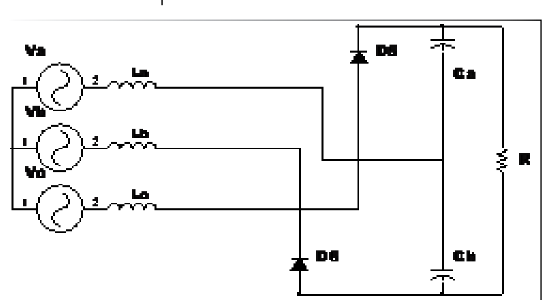
The basic features of a feedback control systems are insensitivity to parameter variations and robustness. The scheme is capable of producing nearly perfect sinusoidal voltage. The closed-loop controller helps to reduce the harmonic content more when compared to the open loop controller. Moreover, the zero-voltage switching reduces the dv/dt and di/dt of each switching device; this in turn decreases the EMI effect and switching losses. The fourth leg of the topology adds to its ability to handle unbalance loading conditions. The scheme gives better results relative to the previous methods [19].

In this paper, by controlling the conduction period of bidirectional switches, power delivered to the load and then the power factor is increased and input current harmonics can be eliminated.

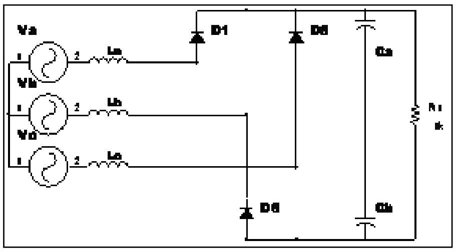
## 2. Analysis

For the circuit analysis, six topological stages are presented in fig 1 a to f, corresponding to the 0 to 180 half period. Two main situations can be identified:

1. In the stage I, III and V, there are only two conducting diodes. As a result, on a conventional three-phase rectifier, the current on the third phase remains null during that interval. In the circuit, the switch associated with the third phase is gated on during that interval. For instance, during the 0 to 30 stage, the bidirectional switch is gated on, so the input current evolves from zero to a maximum value.
2. In the stage II, IV and VI, there are three conducting diodes, one associated with each phase. The three switches are off, so the converter behaves like a conventional rectifier with input inductors.




(a)



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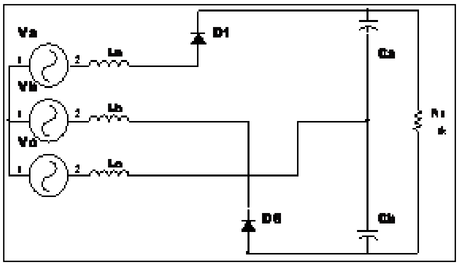

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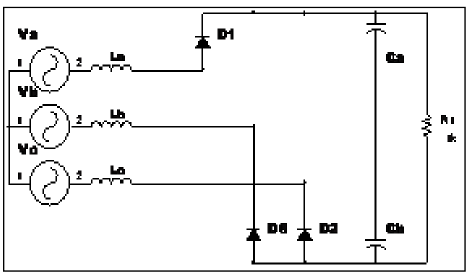

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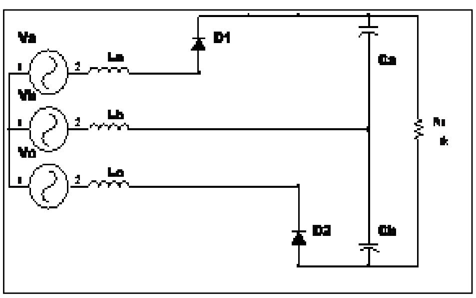

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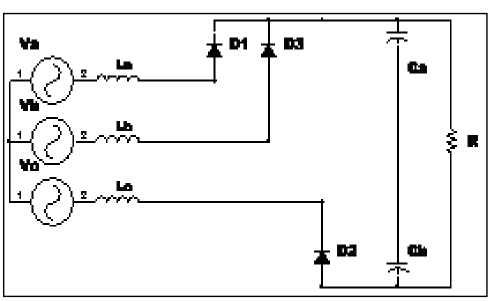

(f)

**Fig. 1 Six topological stages for 0 - π**

**2.1 Bidirectional Switches**

When gate circuit is open and Vdd is present, no current flow from drain to source. When gate terminal is made positive with respect to source, current flows from drain to source.

The construction of bi-directional switch using four diodes and MOSFET is shown in Fig 2.

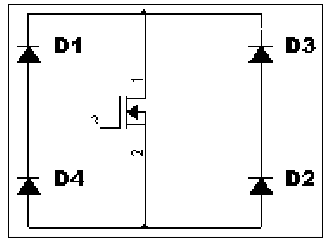


**Fig 2. Bi-directional switch**

During positive half cycle of the input voltage, diodes D1 and D2 are forward biased. When gate signal is applied with respect to source, current flow from drain to source. So the input current is supplied to the load through D1, MOSFET and D2.

During negative half cycle of the input voltage, diodes D3 and D4 are forward biased. When gate signal is applied with respect to source, current flow from drain to source. So the input current is supplied to the load through D3, MOSFET and D4.

**3. Simulation Results**

The simulation diagram of three phase diode rectifier with motor load is shown in fig. 3.

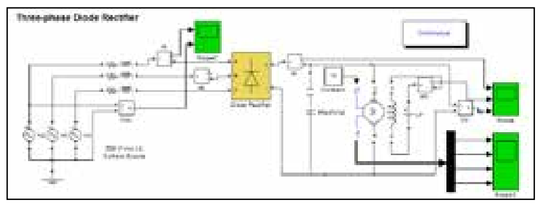

**Fig. 3 Three phase diode rectifier**

The input current waveform of three phase diode rectifier is shown in fig. 4. The diode in each conducts for 120 degree only. From 0 to 30 degree and 150 to 180 degree diode connected in R phase not conducts. So the motor load is disconnected during this period and input current become discntinous. Due to this input current is highly distorted as shown in figure 4. the THD value for this input current I very large as shown in figure 5.

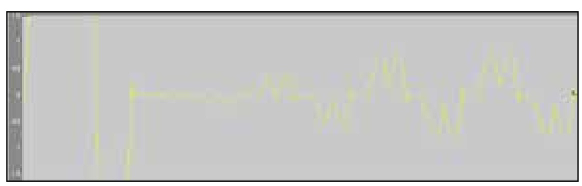

**Fig. 4 Input current waveform**

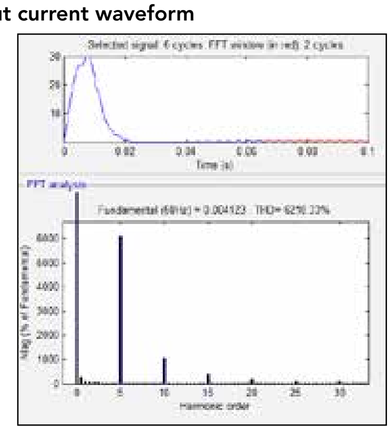


Fig. 5. THD value of input current

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The simulation diagram of three phase diode rectifier with bi directional switch is shown in fig. 6. The bi-directional switches are connected across each phase. The configuration of bi-directional switch is shown in fig 7. The bi-directional switch is connected between source and motor load. When diodes not conduct, the bi-directional switch is triggered and make the input current continuously flows into the load.

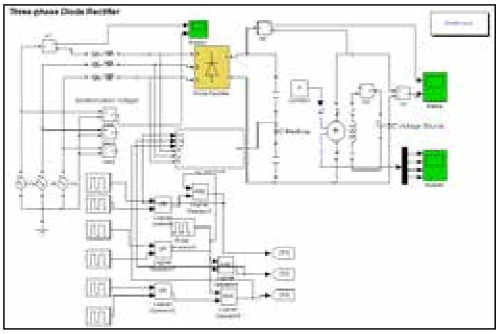

**Fig. 6 Three phase diode rectifier with directional switch**

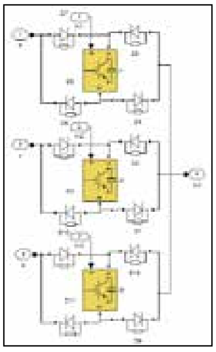

**Fig. 7. Configuration of sub system – AC switch**

The input current waveform and THD of three phase diode rectifier with bi directional switch is shown in fig. 8. The THD value of input current is improved when the directional switches are used and input current waveform is also improved with sinusoidal form.

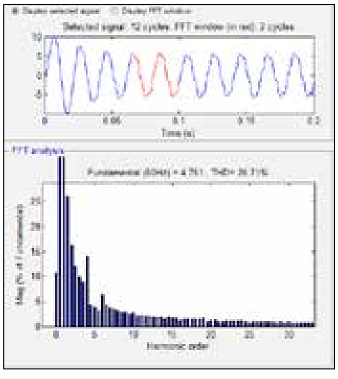

**Fig. 8 The input current waveform and THD of three phase diode rectifier with bi directional switch**

The load test on DC motor was performed and reading was tabulated in the table. 1. When the motor is loaded the input current increases gradually and therefore input power is also increases gradually. So the performance of the DC motor is improved.

Table 1. Load test on three phase DC Motor

| TORQUE | I Amps | V Volts | SPEED RPM | INPUT POWER Watts | OUTPUT POWER Watts | EFFICIENCY % |
|---|---|---|---|---|---|---|
| 0 | 1.6 | 235 | 1710 | 376.00 | 0.00 | 0.00 |
| 1 | 2.2 | 231 | 1695 | 508.20 | 177.41 | 34.91 |
| 2 | 2.8 | 229 | 1681 | 641.20 | 351.89 | 54.88 |
| 3 | 3.8 | 225 | 1667 | 855.00 | 523.44 | 61.22 |
| 4 | 4.7 | 222 | 1655 | 1043.40 | 692.89 | 66.41 |
| 5 | 5.9 | 220 | 1644 | 1298.00 | 860.36 | 66.28 |
| 6 | 7.1 | 218 | 1634 | 1547.80 | 1026.15 | 66.30 |
| 7 | 8.2 | 215 | 1617 | 1763.00 | 1184.72 | 67.20 |
| 8 | 9.1 | 212 | 1609 | 1929.20 | 1347.27 | 69.84 |
| 9 | 9.6 | 210 | 1603 | 2016.00 | 1510.03 | 74.90 |
| 10 | 9.9 | 209 | 1594 | 2069.10 | 1668.39 | 80.63 |

The relationship between output power and efficiency for Load test is shown in figure 9

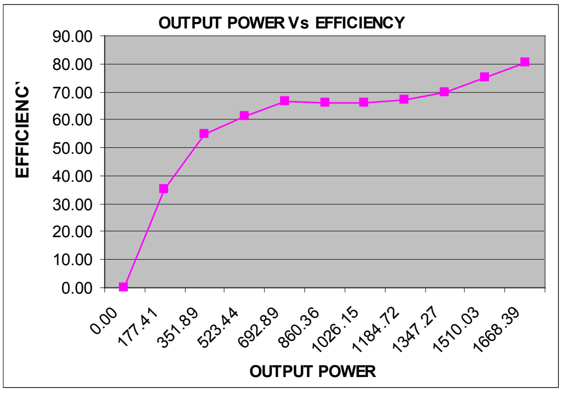


**Fig. 9: Variation of efficiency with output power for Load test**

## 4. Conclusion

The simulation results are obtained for three phase rectifier with and without bi directional switches show that sinusoidal input supply current waveform presents at the input stage. Experimental results obtained from three phase DC motor shows that improved power factor presents at the input stage. A power factor and input current THD improvement for a DC motor load has been verified. Due to the low-frequency operation of the front bi-directional MOSFET switches, the gating circuit is simple, and more reliable. The low-frequency operation provides low switching losses. The MOSFET based bi-directional switches conducts only a small fraction of the total cycle, yielding a negligible switch KVA rating. With these excellent rectifier power factor capabilities, the converter will be an excellent energy saver in a clean power environment.

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