3-Phase 3-wire IGBT based Delta PWM type Voltage optimizer

3 Phase Vector Controlled Energy Saver

By

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Vector Controlled Voltage Optimizer - Three phase delta IGBT PWM type

MEDI has designed and developed three phase three-wire input, three-wire output (delta in delta out) Static voltage optimizer. The main advantage of this development is it works without neutral. Because the unit does not require neutral it is not dependant on the availability or the quality of the neutral line. But single phase loads can be connected from any of the phase output to the existing neutral.

This is an IGBT based delta PWM topology - 100A to 500A each phase.

Advantages of delta PWM are –
PWM is made between phase to phase instead of neutral to phase.
Because of this neutral is not required for the working of unit. And the output has potential with existing neutral. Three phase load can directly be connected across three wire output. And single phase load can be connected from any one of the output to existing neutral.

Other advantage of delta PWM is only three half bridge IGBT modules are needed for three phase voltage regulation.

The only disadvantage of delta PWM is that voltage can be varied in all three phases together, cannot be independently varied.

This is a three phase vector addition / subtraction Voltage Optimizer that can be used for buck-only or boost-only or buck-boost voltage regulation with an accuracy of +/-1%. The duty-cycle of the PWM is controlled by the DSP which has a PWM resolution of 1ns step so an accuracy of much better than 1% regulation can be obtained.

This is an SMPS type voltage optimizer for mains voltage (AC input and AC output). This is a new delta PWM switching topology where **PWM is made directly in 3-Phase AC-to-AC**, without adding any harmonic distortion. In this topology there is no need to convert the AC input to DC and again convert it back to regulated AC output. This simplifies the design, reduces the component count and improves the efficiency and reliability. The power stage is a delta 3-Phase IGBT chopper control. The chopping frequency is around 20KHz which ensures absolute silent operation and pure sine wave output (does not produce any waveform distortion). It has a special feature of 'Active Clamping' there is no switching at unclamped inductive load which will cause high surge during turn-off.

Power topology – It is a two phase interleaved switching circuit, each power stage switching in 180 degrees out of phase. The switching frequency in each phase is 20KHz so the resultant switching frequency in the final output is 40KHz. Very low ripple current in input and output due to inter-leaved switching.

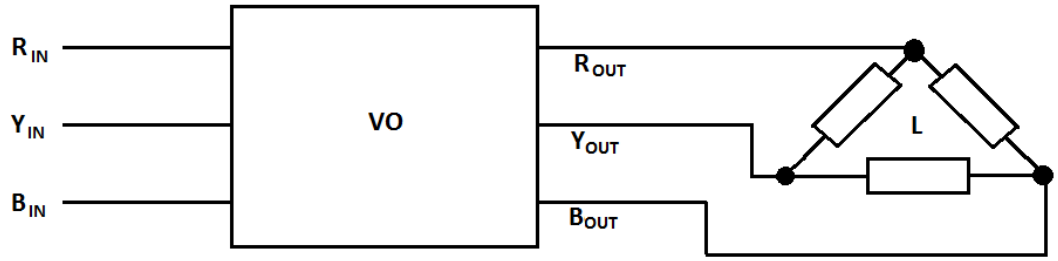
Advantage of three wire delta conversion – Voltage optimization without neutral has a unique advantage. Sometimes, if the input neutral is floating or of high impedance at the time of load imbalance there will be a high drift in voltages in the three phases with respect to the neutral of the voltage optimizer; this will cause reliability issues for the voltage optimizer. Due to the imbalanced load or non-linear load, the voltage optimizer should handle high neutral current so the voltage

optimizer should be designed in a way it should handle such high currents. Our delta voltage optimizer does not have any neutral so these concerns do not come into picture.

For three phase delta loads like three phase delta motor, delta input transformer etc regulating the voltage with respect to neutral and then feeding to delta is not reliable because it will depend on the neutral's quality. The balance in delta will change if there is any neutral open or neutral floating / high impedance. Delta to delta voltage optimization is the most reliable method as the regulation of the output voltage is irrespective of the neutral. Neutral floating / high impedance will not affect the regulation of the voltage optimizer.

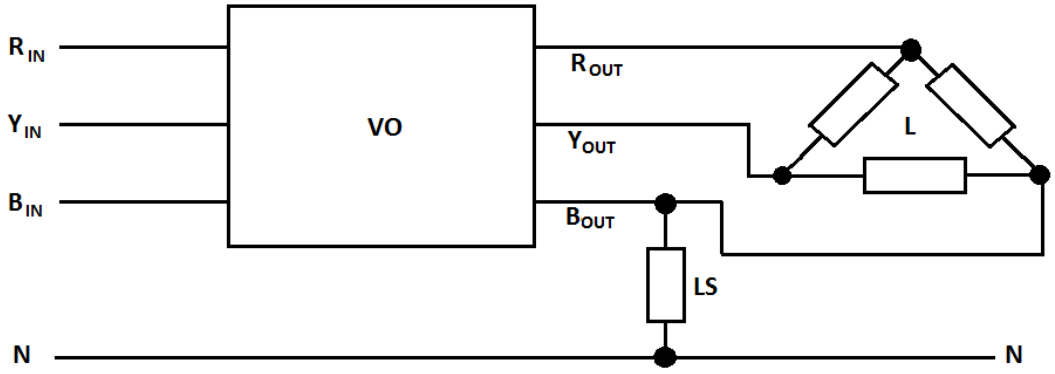
In a four wire system, if the load is non-linear there will be heavy neutral current. In case of imbalanced loads also there will be a neutral current.

The 3-phase 3-wire system is the most efficient power transmission method and more economical than 3-phase 4-wire system or single-phase or two-phase systems at the same voltage because it uses less conductor material to transmit same electric power.



(a)

Connection of 3-Phase Delta Load



(b)

Connection of 3-Phase Delta Load and single phase load

Active Clamping - One of the major challenges we face in AC to AC PWM switching is the unclamped inductive switching. This will lead to high energy loss because of the spikes and huge snubber is required. In our design, there is no unclamped switching because of 'Active Clamping' so snubber circuit is not required.

The DSP will sense the fly back voltage direction as well as the incoming phase sequence and will periodically and cyclically disable the PWM and turn on the IGBTs to clamp the fly back voltage back to the incoming 3 phase line so that efficiency will increase and the IGBT will operate in spike free active clamped inductive switching.

Bypass arrangements – Internal bypass switch is already provided. This will give a bypass without any interruption in the output. The system will activate the internal bypass when there is any abnormal condition like excess temperature, excess load or any fault in the system.

Additionally, if the system needs to be switched out of circuit so the site is supplied with mains electricity supply the system can be incorporated with a Manual Bypass switch.

The system is highly reliable and safe as it is fully electronic, there is no moving part which can cause damage due to wear and tear or require regular maintenance. All protections are inbuilt in the system to protect it in hazardous conditions. Active clamping, IGBT de-saturation protection and soft turn-off, Miller clamping to avoid shoot through conduction in IGBT power stage, short circuit protection, lightning and surge protection, EMI /RFI filter are all included in the system.

Highlights of this design are:

- Fully solid state, no moving parts thus less maintenance
- Due to specialty of the power topology 3 Phase 3-wire system is possible. Can also use 4-wire if needed by simply connecting the existing neutral to the load.
- PWM type voltage regulation results smooth variation of the voltage and no need of voltage tappings.
- Tight regulated output +/-1 % or better. Saves more energy than SCR controlled tap changing or fixed step-down transformer type energy savers.
- High correction speed.
- Only the difference power is processed through the system resulting higher efficiency.

In a resistive or inductive load the wattage is directly proportional to the voltage square. So if there is a 2% increase in the voltage, the wattage is the square of that 2% which amounts big. The losses due to poor regulation in SCR control tap changing type of voltage stabilizer, fixed transformer, servo stabilizer are higher than IGBT PWM type of stabilizer. In an SCR control tap changing type of voltage stabilizer, fixed transformer, servo stabilizer, the best regulation possible is only 3% to 5%. If using these methods we should achieve 2% tight regulation, 220 * 2% = 4.4V, so for every 4.4V increment we have to use an SCR tapping. This will result in huge number of SCRs and this will lead to nuisance as for every 4.4V change in the input the SCR should fire and the tap change to take place. Moreover, with relays or SCRs the tap variation is in steps whereas IGBT PWM is a smooth variation with a resolution of 1ns steps. Though 0.25% regulation is possible we are regulating at 1.0% in order to avoid feed-back oscillation.

FEATURES

- Three phase three wire operation eliminates the neutral connection
- Only three half bridge IGBT modules required for the power stage
- Direct AC-AC conversion without rectifying to DC improves the efficiency, reliability and reduces the components.
- Rapid cycle by cycle correction of output. It can correct sudden fluctuation in the line voltage. For example using a welding machine in the same line will cause sudden fluctuation in the line voltage which cannot be corrected with conventional relay type and servo controlled voltage stabilizers, where Static Voltage Optimizer can correct it.
- Output regulation of +/- 1% which is impossible in conventional stabilizer.
- No distortion in output waveform.
- Overload cut off and short circuit cut off
- Over voltage and under voltage cut off.
- Automatic bypass in case of hazard/ failure.
- LCD for displaying all parameters.
- The actual power, optimized power and saved power displayed with date and time stamp.
- Small transformer size ($1/5^{th}$ of the capacity)
- Compact size and light weight
- 20KHz PWM control resulting silent operation.
- IGBT power stage. Highly reliable.
- Fully solid state. No moving part, hence more life and no maintenance.
- Periodically the unit goes to fully uninterrupted bypass for a short while and measures actual power consumed by the load and comes back to voltage optimize mode, measures the reduction in the power and calculates how much energy is saved. This is measured using class 0.5 certified 3 phase energy meter. These parameters are displayed in the LCD along with other parameters like voltage, current, power factor, harmonics etc
- System has built-in datalogger. All the parameters are periodically saved to flash memory with date and time stamp. The device is also having a wireless Zigbee communication

interface. A computer or other device can wirelessly monitor or download the data and thereafter upload to the Internet.

A 4-line LCD present in the system will indicate the following –

- Energy (KWH) used with VO
- Energy (KWH) used without VO
- Energy (KWH) saved with VO
- Mains input voltage
- System output voltage
- Phase load in KVA
- Frequency in Hz
- Input current in each phase
- Total Watts (total active power) and Watts in each phase
- Total KVAR (total reactive power) and KVAR in each phase
- Total KVA (total apparent power) and KVA in each phase
- Power factor in each phase
- Voltage THD in each phase
- Current THD in each phase
- Percentage of imbalanced load
- Percentage of imbalanced voltage
- Load current in Amps
- Fault condition like overload, high temperature, bypass active

Buzzer indication for faulty conditions –

- Overload
- High temperature

The system will have a temperature sensor, if the temperature rises above the set limit, the fan will switch on and when the temperature comes down the fan will switch off. Due to any hazardous condition the temperature reaches above excess temperature limit, the system will go on automatic bypass without interruption (make before break) and will shut down the PWM. When the temperature reaches back to the safe limit, the optimizer will come back to normal working without interruption. The system will indicate fault signal through buzzer, display on LCD and through wireless zigbee interface.

Specification

Capacities	66KVA – 100A each phase 100KVA – 150A each phase 200KVA – 300A each phase 300KVA – 450A each phase

Control type	DSP based IGBT PWM switching
Input Voltage Range	381V to 433V
Output Voltage	381V
Regulation	+/- 1%
Efficiency	>97%
Input Frequency	45Hz to 55Hz
Output Wave Form	Same as Input
Effect of Power factor for 10% to 100% load	Nil
Display	LCD for various parameters like – • Energy (KWH) used with VO • Estimated Energy (KWH) used without VO • Estimated Energy (KWH) saved with VO • Mains input voltage • System output voltage • Phase load in KVA • Frequency in Hz • Etc…
Rate of Correction	1000V per second
Ambient Operating Temperature	0 to 50 deg Celsius
Duty cycle	Continuous
Nature of Cooling	Forced Air cooled
Mains bypass	Un-interruptible auto bypass to mains when VO is in cut off mode and mains input voltage is between 381V to 467V.
Protections	Overload Short Circuit High voltage Low voltage
Trip and restart	Auto
Transformer	Less than $1/5^{th}$ size of the rated VA