Buck and boost Static Voltage Stabilizer

Three phase three wire IGBT delta PWM technology

By

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INTRODUCTION

Static Voltage Stabilizer : Three phase three wire IGBT delta PWM technology

Nearly a decade ago, MEDI released the first design of Static Voltage Stabilizer using IGBT PWM technology. Our research has never stopped. We are pleased to announce the release of a cutting edge technology development in the field of Static Voltage Stabilizers using IGBTs but with delta PWM topology and three phase three wire system.

MEDI has designed and developed three phase three-wire input, three-wire output (delta in delta out) Static voltage stabilizer.

This is an IGBT based delta PWM topology three phase static voltage stabilizer up to 200KVA. This is a three phase vector addition / subtraction Voltage Stabilizer that can be used for buck and 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 stabilizer 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.

The control section is based on dsPIC controller which ensures quick correction of output which is not possible in conventional relay type stabilizer or servo controlled stabilizers. The circuit is having LCD display which will show all parameters like: input voltage, output voltage, connected load, your company name (We will program your company name in the dsPIC at the time of technology transfer) etc.

Since the circuit is fully solid state (no mechanical or moving parts) there will not be any wear and tear like the brush tear in servo stabilizer or relay degrading in relay based stabilizer.

This is especially useful in places where we need very fast correction speed, constant output voltage, overload current limiting and short circuit protection, soft start, high voltage cut-off and low voltage cut-off, automatic bypass, no wear and tear, long life and maintenance free which is impossible with other conventional relay type or servo control stabilizers.

Why three phase three wire??

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.

Voltage stabilization 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 neutral of the voltage stabilizer; this will cause reliability issues for the voltage stabilizer. Due to imbalanced load or non-linear load, the voltage stabilizer should handle high neutral current so the voltage stabilizer should be designed in a way it should handle such high currents. Our delta voltage stabilizer does not have any neutral so these concerns do not come into picture.

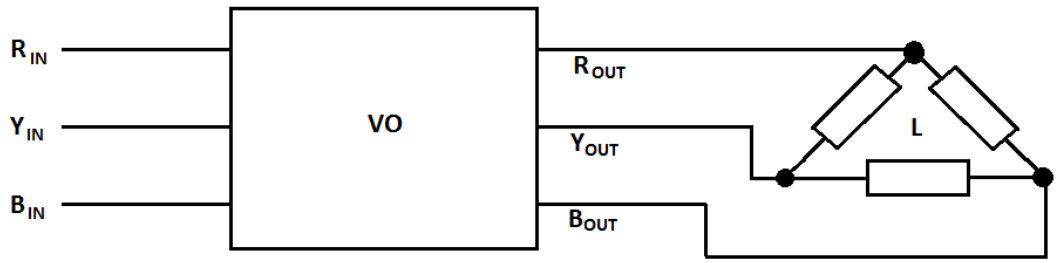
For three phase delta loads like three phase delta motor, delta input transformer etc regulating the voltage with respect to neutral and then feeding to delta is not reliable because it will depend on the neutral's quality. The balance in delta will change if there is any neutral open or neutral floating / high impedance. Delta to delta voltage stabilization 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 stabilizer.

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

Advantages of delta PWM are –

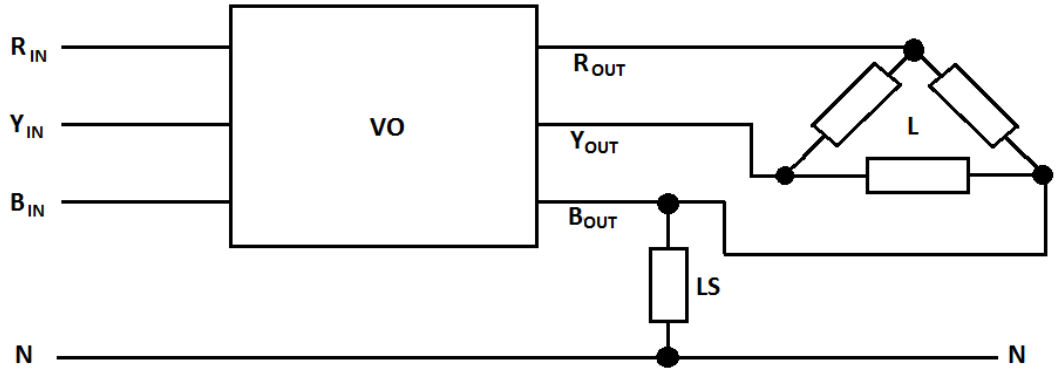
PWM is made between phase to phase instead of neutral to phase. Because of this neutral is not required for the working of unit. And the output has potential with existing neutral. Three phase load can directly be connected across three wire output.

For single phase loads, it can be connected from any one of the phases to the existing neutral. See the figure below -



(a)

Connection of 3-Phase Delta Load



(b)

Connection of 3-Phase Delta Load and single phase load

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

This is a three phase vector addition and subtraction Voltage Stabilizer that can be used for buck and 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.

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.

EFFICIENCY

Efficiency calculation of a 100KVA unit
Input range : 330V to 430V (+/-13%)
Output voltage : 380V +/-1%
Output current : 150A

Transformer loss –
Transformer KVA : 13KVA
Transformer efficiency : 95%
i.e., Transformer loss = 5%
Therefore, 13KVA × 5/100 = 650VA

IGBT conduction loss of FF150R12RT4
IGBT current at full load : 22.8A
Vce(sat) collector-emitter saturation voltage in worst case : 2.1V
i.e., Conduction loss = 22.8A × 2.1V = 47.88W
Therefore, 47.88W × 3 IGBTs = 143.64W

Switching loss at 22.8A
T(on) loss at 22.8A is <4mJ
T(off) loss at 22.8A is <4mJ
T(on) + T(off) loss is <8mJ

Switching loss at 20KHz = 8mJ ×20000Hz = 160000mW
i.e, 160W × 3 IGBTs = 480W

Switching loss vs current graph to be copied from IGBT datasheet

Total loss –
Transformer loss : 650W
IGBT conduction loss : 144W
IGBT switching loss : 480W
Total loss : 1274W
i.e, 1.274KW

$$\text{Overall efficiency} = \frac{(100\text{KW} - 1.274\text{KW})}{100\text{KW}} \times 100 = 98.726\%$$

Efficiency of a 100KVA system is 98.726%

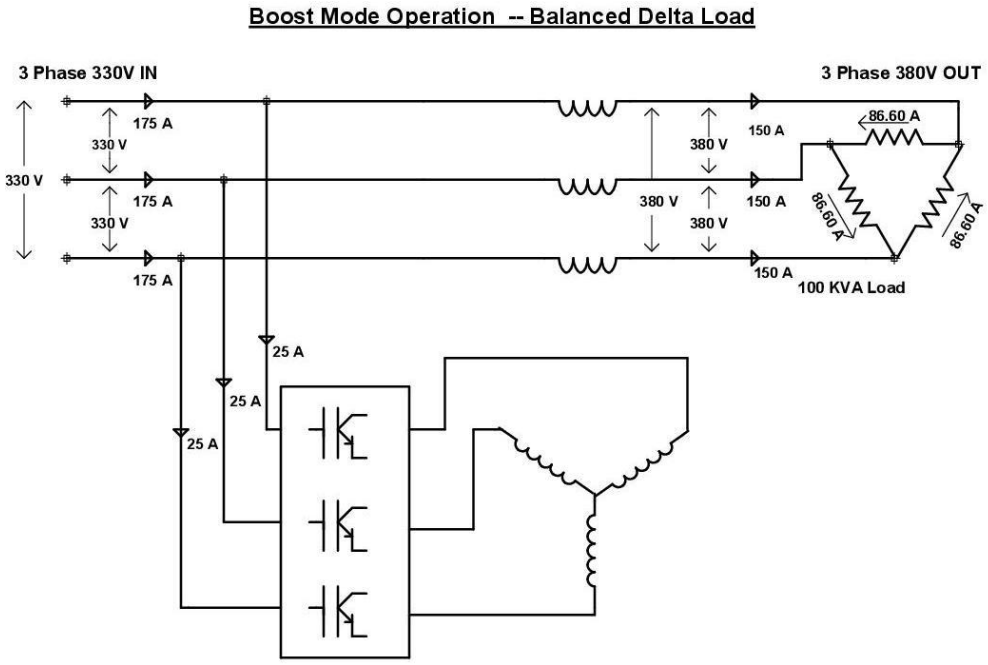


figure 1

In figure 1, you can see the boost mode current and voltage for delta balanced load

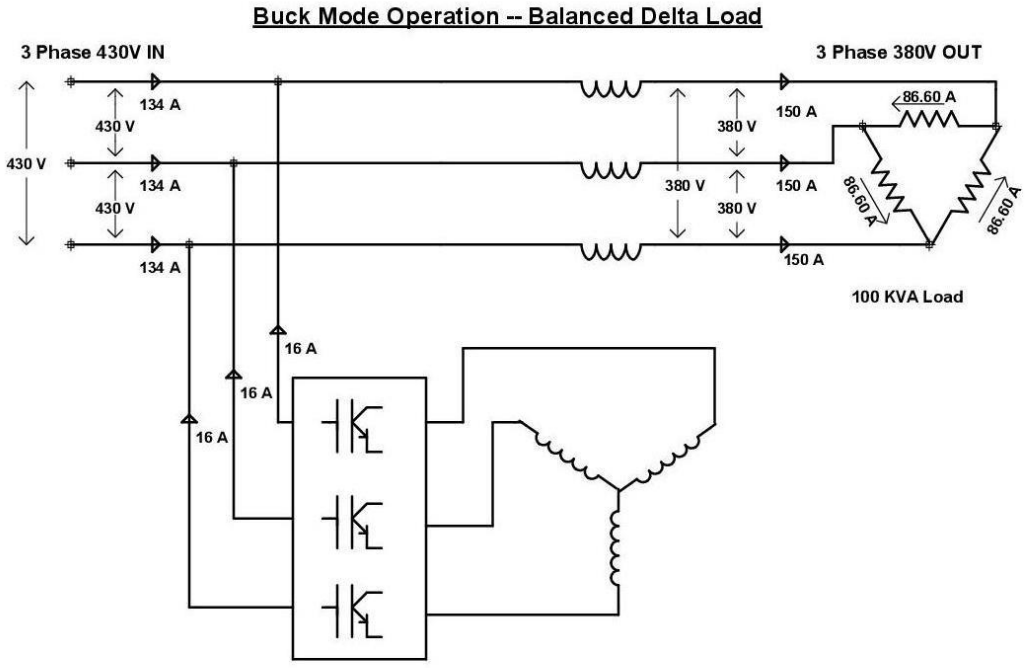


figure 2

In figure 2, you can see the buck mode current and voltage for delta balanced load

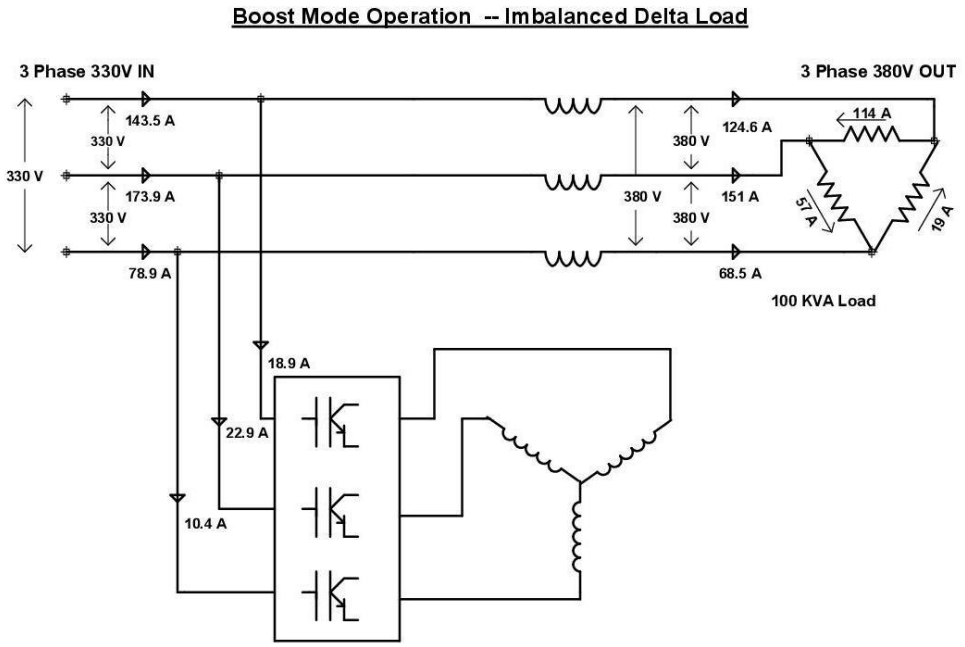


figure 3

In figure 3, you can see the boost mode current and voltage for delta imbalanced load

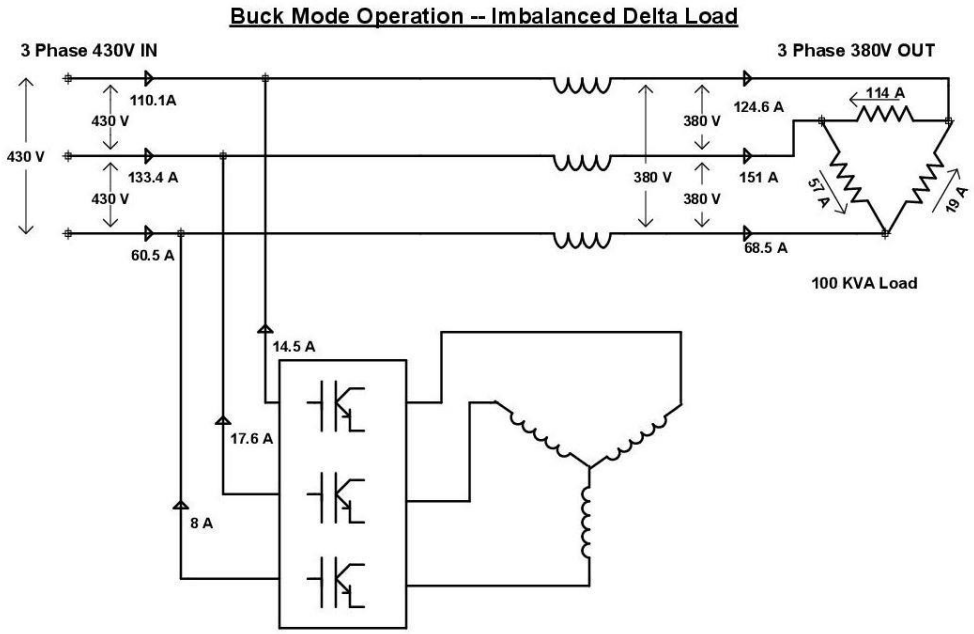


figure 4

In figure 4, you can see the buck mode current and voltage for delta imbalanced load

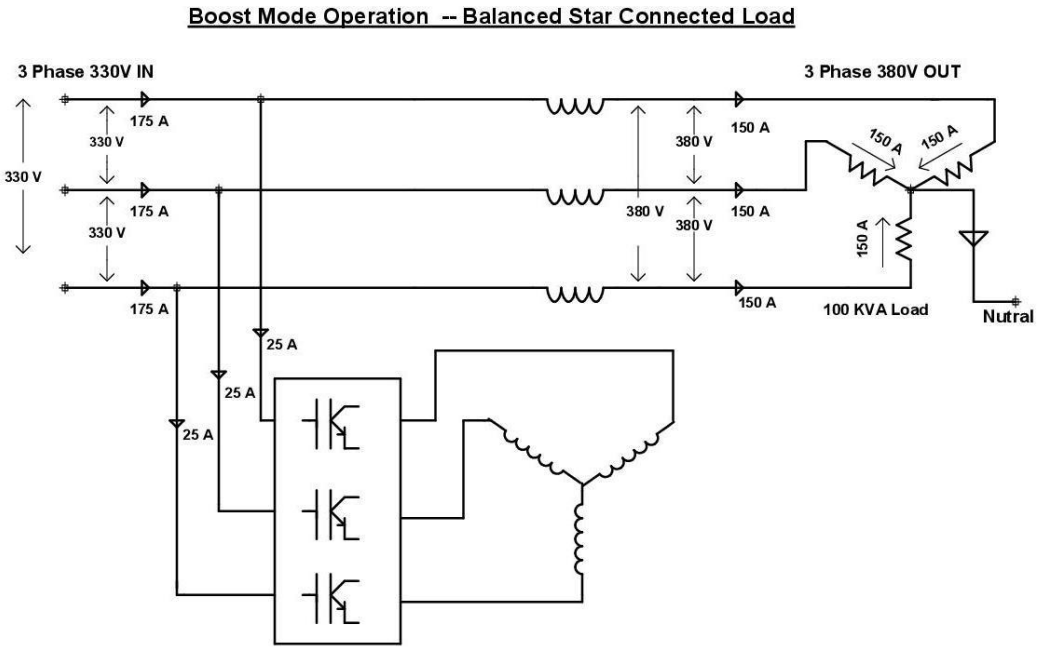


figure 5

In figure 5, you can see the boost mode current and voltage for star balanced load

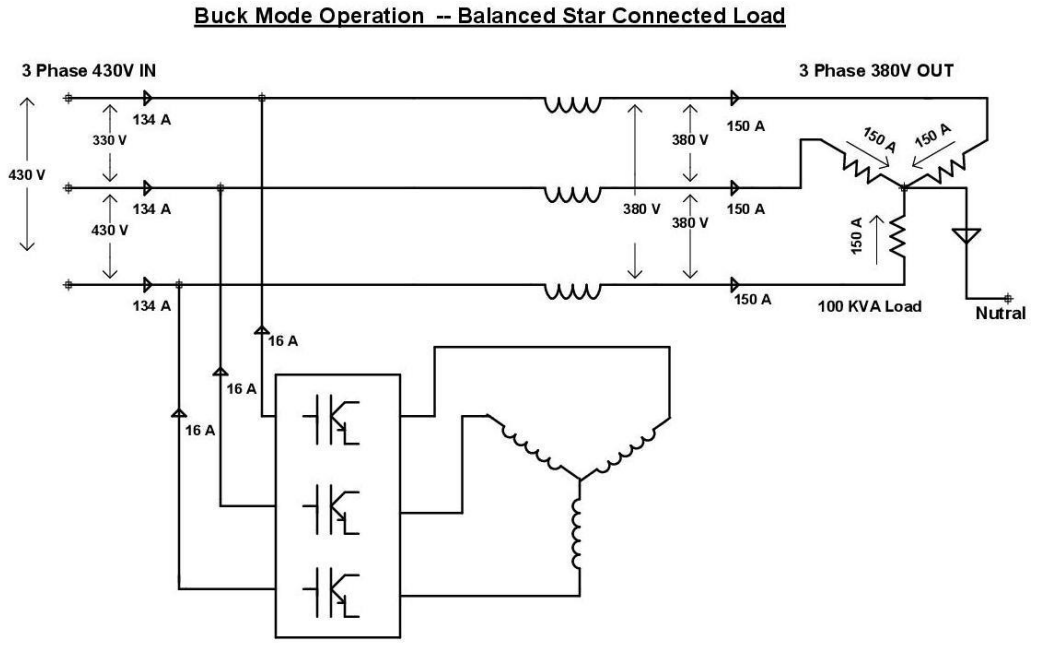


figure 6

In figure 6, you can see the buck mode current and voltage for star balanced load

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.

FEATURES

- Three phase three wire operation. The PWM is done directly on Phase to Phase, not on neutral to phase. Output is regulated for phase to phase voltage and hence for existing neutral to phase voltage also. So Neutral not required for the working of the unit. PWM type voltage regulation results smooth variation of the voltage and no need of voltage tappings.
- Neutral quality or availability is not effecting the output regulation or working of the unit.
- IGBT based PWM type voltage stabilizer which has tight regulation and fast correction speed. Output regulation of +/- 1% unachievable with SCR tap changing/ servo stabilizers.
- 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
- Only the difference power is processed through the system resulting in small size buck-boost transformer and higher efficiency.
- 20KHz PWM control resulting silent operation and no distortion in output waveform.
- Automatic uninterruptable bypass in case of hazard
- Overload and short circuit protection provided
- Technology up to 200KVA three phase (up to 300KVA in +/-10% range)

- Four line LCD to display all parameters
- System has built-in data logger (optional). All parameters are periodically saved to flash memory with date and time stamp.

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 stabilizer will come back to normal working without interruption. The system will indicate fault signal through buzzer and display on LCD.

Approximate Bill of Material (BOM) –

Capacity (3ph)	Input range	Output	Buck/boost Transformer VA	IGBT current	Output current	Bill of Material (BOM)
50KVA	330V to 430V (+/-13%)	380V	6.5KVA	11.4A	75A	Rs.50000
50KVA	310V to 450V (+/-18.5%)	380V	9.2KVA	17.2A	75A	Rs.58000
50KVA	300V to 460V (+/-21%)	380V	10.5KVA	20.2A	75A	Rs.60000
75KVA	330V to 430V (+/-13%)	380V	9.75KVA	17.1A	113.5A	Rs.62000
75KVA	310V to 450V (+/-18.5%)	380V	13.8KVA	25.8A	113.5A	Rs.66000
75KVA	300V to 460V (+/-21%)	380V	15.75KVA	30.3A	113.5A	Rs.68000
100KVA	330V to 430V (+/-13%)	380V	13KVA	22.8A	150A	Rs.68000
100KVA	310V to 450V (+/-18.5%)	380V	18.4KVA	34.4.A	150A	Rs.72000
100KVA	300V to 460V (+/-21%)	380V	21KVA	40.4A	150A	Rs.75000
200KVA	360V to 440V (+/-10%)	400V	20KVA	32A	290A	Rs.80000
200KVA	330V to 430V (+/-13%)	380V	26KVA	45.6A	300A	Rs.90000
300KVA	360V to 440V (+/-10%)	400V	30KVA	48A	435A	Rs.105000

Cabinet extra.

Technology cost

Technology transfer up to 200KVA three phase – Rs.18 lakhs

Discount of Rs.5 lakhs for all customers who have purchased MEDI's IGBT based static voltage stabilizer single phase up to 70KVA and three phase up to 200KVA.