Present Scenario of Voltage Regulators in India

1. Introduction:

With the increasing distortion and interference on the utility lines and also with the increasing use of sensitive equipment, power quality problems have become a major concern, especially for sensitive equipment. However, auxiliary equipment called power conditioning equipment may be utilized to mitigate power quality problems. Employing power conditioning equipment such as voltage regulators and uninterruptible power supplies, problems at the utility side may be prevented from distorting the voltage at the load side. There are various power quality problems at the utility: Voltage sags, voltage swells, transients, voltage interruptions, etc.

Power quality is quite frequently described as “voltage quality” because most power quality problems are voltage quality problems and generally power quality concerns the following groups: Utility, end users (residential, commercial, and industrial), sensitive equipment manufacturers, power conditioning equipment manufacturers, standard organizations (IEC, IEEE, ANSI), research organizations (EPRI, PEAC), consultants, monitoring and measuring equipment manufacturers, architect/engineer facility designers. Also, power quality can be defined with respect to “clean power.” “Clean power” refers to power that has sinusoidal voltage without any distortion and which is at the desired magnitude and frequency. Thus, “dirty power” or “distorted power” could be described as a power that has a distorted sinusoidal voltage or which is outside the desired limits of voltage and/or frequency. “Power quality” or “clean power” is important and necessary especially for sensitive electronic devices designed and manufactured in state-of-the-art technology. Non-electronic equipment used in the past such as motors, incandescent lights, and resistance heaters could tolerate voltage disturbances of ±5 % of nominal voltage.

Lets quickly look at the definitions of voltage transients “Seg” and “Swell”. Sometime “Seg” also term as “Dips” or “undervoltage” and “Swell” as “overvoltage”. Let us discuses about the cause of dirty power or unstable source voltage.

2. Causes of Power Disturbances:

- Power disturbance originate both outside and inside customer facilities.
- Load switching causes surges because of collapsing fields ($-e = L * di/dt$).
- Over loaded power distribution systems can cause significant voltage variations between peak and off-peak hours.
- Significant momentary load changes, such as heavy inrush currents can cause severe voltage variations.

- Black-outs can cause severe voltage surges both on loss and return of power.
- Circuit-breaker tripping and fuse blowing can cause severe surge voltages.
- Large ups and variable-speed drives can cause various surge voltages inside buildings.

3. Results of power disturbances:

- Sags and under voltages can cause component overheating or destruction.
- Surges and over voltages can cause component overheating, destruction or can trigger other electronic components such as SCR's, IGBT.
- Component overheating reduces the life and deteriorates the real reliability as opposed to the estimated reliability based on steady-state conditions of the product.
- False triggering of other components can create nuisance alarm tripping or, worse, can cause overheating or destruction of other electronic components.

4. Limitations with semiconductors:

- Most semiconductor devices are intolerant to surge voltages in excess of their voltage ratings.
- Even a fast surge of a few microseconds can cause the semiconductor to fail catastrophically or may degrade it so as to shorten its useful life.
- Damage occurs when a high reverse voltage is applied to a non-conducting P-N junction.
- The junction may avalanche at a small point due to the non-uniformity of the electric field. In this case, thermal runaway can occur because of localized heat build up and cause a melt-through which destroys the junction.

5. Limitations with current solutions:

- Typical EMI filters are not well damped. This has a dramatic effect on any voltage disturbances, resulting in oscillations inside the EMI filter under any transitional conditions. Severe voltage surges may result from fly-back from saturated inductors looking for a path to release energy.
- Boost converters can be destroyed by surges causing increased energy storage in input filter, the output capacitor is charged to an unsafe level depending on capacitance value and load levels for the DC/DC converter connected to the output of the boost.

6. An Ideal Voltage Regulator (IVR):

An IVR has Infinite correction rate ($dV_0/dt = 0$). It will not allow any variation in output voltage irrespective of load type and supply condition. The definition demands IVR to produce regulated voltage even at zero input voltage.

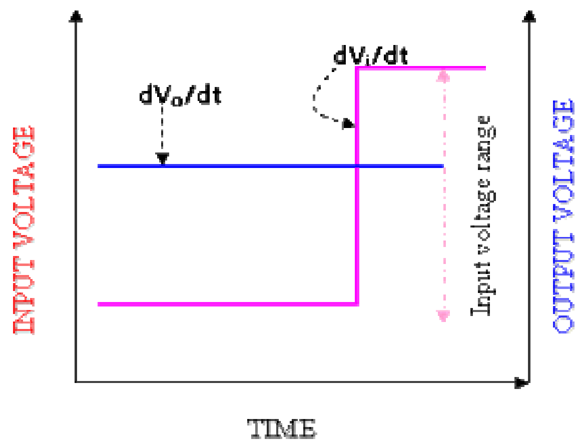

Fig 1: characteristic of IVR

7. Voltage Regulators in General:

It is important to discriminate between Uninterrupted Power Supply (UPS) and voltage regulator (VR) in general. VR doesn't store or generate energy and hence the there must be a minimum voltage available to serve the purpose of regulation otherwise it must be supported by stored energy and hence the UPS comes into the picture. Some of UPS topologies falls in the voltage regulator category but not all. The limit of maximum voltage is imposed by permissible limit of maximum electrostatic stress on components used build VR. We are clear about the minimum and maximum voltage limit to use VR.
There are some topologies available for VR and it has been discussed in brief further in paper.

8. Types of Voltage Regulators:

There are 3 topologies quite common for voltage regulator (refer Fig 2)

1. Electromechanical Servo Regulator.
2. Electronics Tap Switch Regulator.
3. Dual Conversion Regulator.

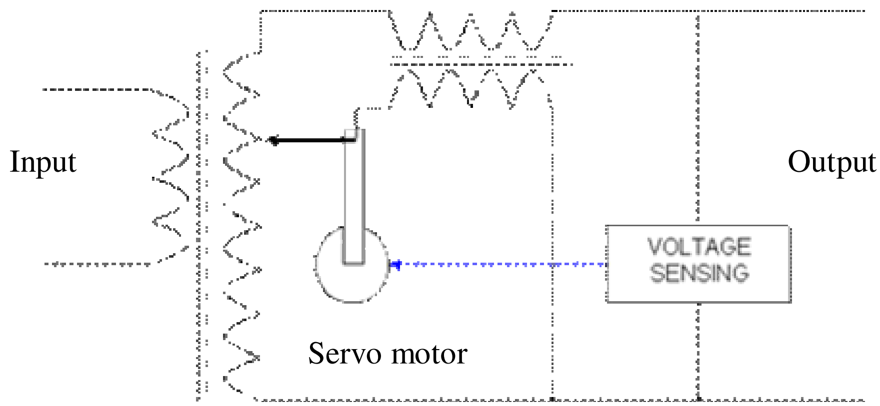

Fig 2 a: Electromechanical Servo Regulator

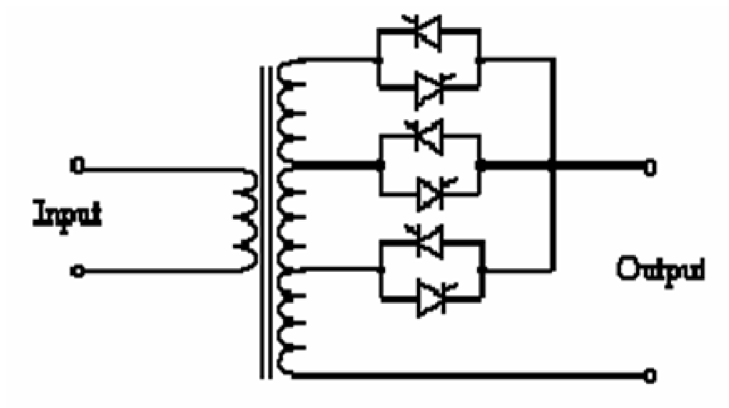

Fig 2 b: Electronic Tap Switch Regulator

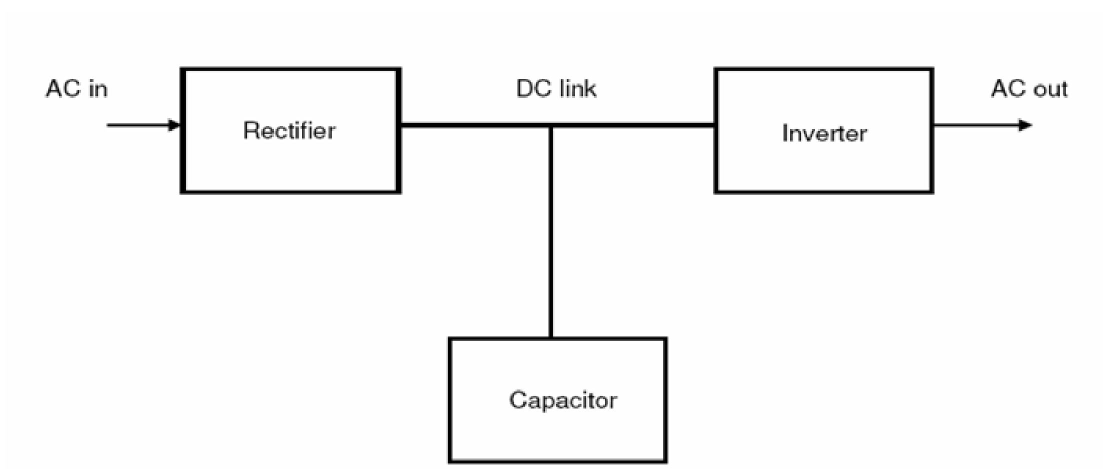

Fig 2 c: Dual Conversion Regulator

8.1 Electromechanical Servo Regulator: IS 9815 is standard is being follow in India. Output voltage is being sensed and corrective command is given to electric motor. This electric motor is moves on auto transformer and the compensation voltage is injected in series of input voltage. Since an electric motor is being related to appropriate position of auto transformer, hence it is called as servo voltage regulator. A servo regulator has its own limitation by technology itself. The control loop includes sensing, error calculation, control law (P, PI, PID etc) and actuator that is motor. The fastest action could be involving min delay possible of each event. The electric motor time constant is typically 0.2 ~ 5 seconds. It mostly depends upon the size of motor. High capacity motor may have even more time constant. This limits the correction rate at most 80 V/sec*. Higher capacity servo may have even low ~10V/sec correction rate. It is a robust against slow voltage variation. Because of it sluggish correction rate, it may pass the voltage fluctuation and hence it is not recommended for sensitive load. Regular maintenance required as it consists moving contact (brush tear, sparking etc).

8.2 Electronic Tap Switch Regulator (ETSR): Multi tap auto or two winding transformer is used to regulation action. These regulators ensure the output voltage with in a range. In India, the output voltage range is limited between 200 to 240 vac, 50Hz. The typical input output Voltage relation is shown in Fig 3. In general, input voltage is sensed and the control action will switch to suitable tap. ETSR switch full load from one tap to other. As per IS 8448 standard ETSR is limited to 5kVA per phase. ETSR is not recommended for highly inductive or capacitive load. If it is used it may lead to produce switching surge and the other appliances which are connected parallel to it, will be exposed to these surges. It is also not recommended to use ETSR at high fluctuating sites. But at all this is cheapest one could be available in market.

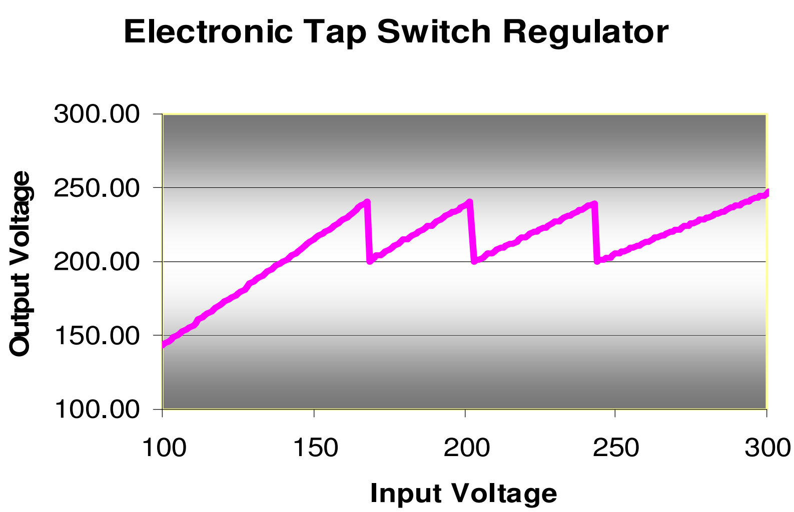

Fig 3: Input Output Characteristics of Electronic Tap Switch Regulator

8.3 Dual Conversion Regulator (DCR): These regulators are ideal for any load and show the closest performance to IVR provided the input range is with in the limit. Unregulated input AC power is converted into DC and DC is converted to regulated AC power. By topology, surges, fluctuation and voltage variation can be filtered out. Even frequency variation is also being control to some extend. DCR is best in any sensitive load and much expansive than we have discussed so far. Overload capacity of electronics is very poor and hence DCR has low overload capacity. It is also not recommended to use it for direct motor start application until unless the DCR has been oversized. Due to high cost, DCRs are very less popular and customized for user specific.

9. Smart Regulator:

As we have discussed so far, Servo has continuous voltage transfer characteristic but it is sluggish. ETSR is fast but it is non continuous voltage transfer characteristic. Dual is best but high cost makes it less demanding in market. Some how, one can think of a smart regulator which can optimize the desirable features of each one.

9.1 Proposed Topology: It could say, it is an improved version of Servo Regulator the only difference is the slow electric motor is replaced by high speed power electronics circuitry. Same as in DCR, there is dual conversion (AC-DC-AC) and compensation voltage is being injected in series of input voltage.

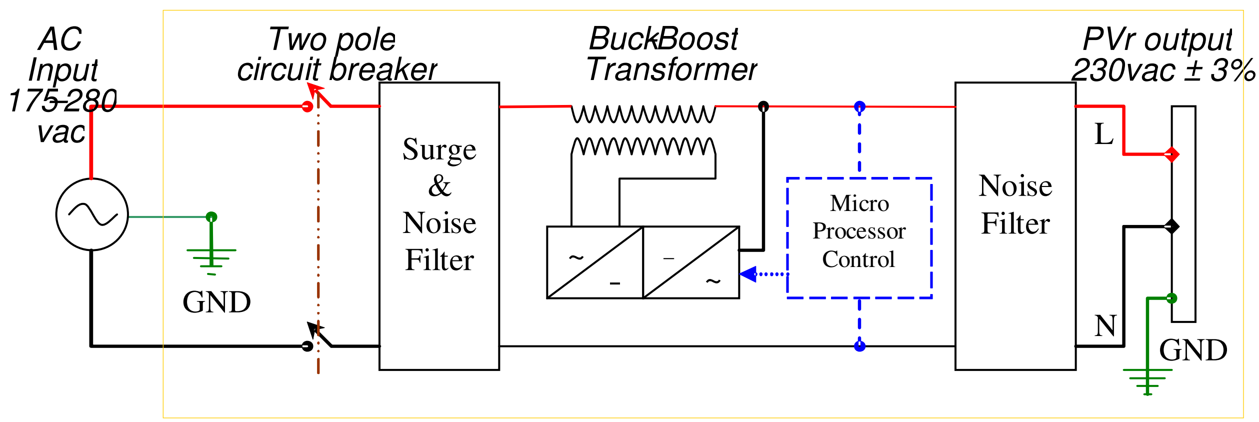

Fig 4. Smart Regulator “PVr”

Unlike in DCR, the electronics is rated to fraction of capacity and unlike in servo, only one buck-boost transformer is used (servo needs to have two transformers). The proposed topology is also known as “Precision Voltage Regulator” (PVr) and it is commercially available from Elcomponics Technologies India Pvt Ltd, Noida, India. PVr comprises chief features of Servo and Dual conversion Regulators. It has continuous voltage transfer characteristics at faster rate of correction. It is measured the rate of correction for PVr is better than 2500 V/sec. its low impedance make it compatible with all types of load. PVr is quite suitable for direct motor start as inrush current is not directly flow through electronics. Hence, PVr take care the limitations of the other regulators.

10. Summary:

- Reasons and definition used for voltage regulator is been discussed.
- Ideal voltage regulator has infinite correction rate irrespective of load and supply conditions.
- Due to limitations on components used, IVR is impossible to implement.
- Regulator with power back up is generally referred as UPS (except stand by UPS).
- Servo Regulator is recommended where the low fluctuation and slow voltage variation is observed. ETSR is recommended for resistive load and of below 5kVA per phase capacity. DCR is recommended for mission critical load but doesn't include direct start of electric motor.
- PVr is recommended in most of the cases and low dependability of load type.
- This paper has given the general inputs to the end user to select the appropriate regulator for application specific.

About the author:

Mr Rahul Rahulanker is B.Tech in Electrical (2002) from HBTI, Kanpur, India and Master in Power Electronics, Dept of Electrical Engg (2006), Indian Institute of Science, Bangalore, India. He has been active in power quality since 2006. He has worked with "Ashok Leyland ltd, India" on hybrid Vehicles and being with Elcomponics Technologies (I) Pvt Ltd since 2007. He is major in SMPS, Embedded System, Power Electronics Controlled Industrial Drives.

Mr Dhirendra Tiwari is B.Tech in Electrical (2004) from KNIT, Sultanpur, India and Master in Power Electronics, Dept of Electrical Engg (2006), Indian Institute of Science, Bangalore, India. He has been active in power quality since 2007. He has worked with "Tata Motors ltd, India" on automotive wiring harness design & development and being with Elcomponics Technologies (I) Pvt Ltd since 2007. He is major in SMPS, Analog circuit, High Power Converters and Industrial Drives.

ETIPL (located in Noida, UP, India) is manufacturer of custom specific power supplies and Line Conditioner and Automatic Voltage Regulator with the vision of design to meet the challenge for international power conditions.