Effective Voltage Regulator For Domestic Loads

B.Poojitha, S.LakshmiVasavi, G.Satya Kalyani, G.Naveen Kumar
1Under graduate student, 2Under graduate student, 3Under graduate student, 4Associate professor
1Electrical and Electronics engineering,
1Andhra Loyola Institute Of Engineering and Technology, Vijayawada, India

Abstract: This paper presents an effective voltage regulator which possess hardiness, less cost and subsistence in a way to avoid power electronic devices the above features make it suitable for domestic loads. So, that operational cost in power quality improvement is reduced. The proposed voltage regulator consists of multi winding transformer, Circuit Breakers which acts as switches Distinct Voltage Compensation steps are attained by modifying the connections and changing polarity between primary and secondary windings. The multi winding transformer has been optimized to attain a greater efficiency and low cost voltage regulator. A controller unit monitors the output voltage and sets the minimal compensation step. Simulation and programming results are represented to exhibit the voltage regulator operation.

IndexTerms – Polarity switching, Serial voltage Compensation, domestic loads, voltage regulation, multi winding transformer

I. INTRODUCTION

In the present scenario domestic loads are mostly effected to long duration voltage variations. The voltage variations here refer to over voltage and under voltage and these are the major drawbacks in the distribution network. In India, the standard voltage limits are 230 ±7%. The voltage range should be maintained with in the permissible limits. The major drawback of the distribution network is occurring of over voltage and under voltage due to long distance because of this voltage fluctuations the domestic loads are mostly affected. Domestic loads refer to house hold appliances which consume electrical energy. The devices are designed with reference to the standard limits. Otherwise the appliances may get damaged.

Long duration over and under voltages will occur in rural areas as compared to the urban areas because customers are in scattered configuration to the distribution. So that length of the transmission line is more. If the length is more copper losses are more due to which the efficiency is reduced.

Now a days the existing voltage regulators are designed by using power electronic devices. In order to run them we need external devices like firing angle control equipment and the switching sequence of the SCR’s we’re facing commutation issues, overheating, malfunctioning of devices and harmonics are produced which disturbs the entire operation. It results in increase in the operational cost of the regulator.

To avoid the power electronic device losses and distribution losses we need to place a compensating equipment in between the load and the distribution system. Here we preferred voltage regulators. Now we are proposing the voltage regulator without any power electronic devices and it has characteristics like hardiness, less cost and high efficient. These characteristics can satisfy the domestic load needs. Losses are also very less as compared to the conventional voltage regulators.

II. OPERATING PRINCIPLE OF VOLTAGE REGULATOR

The effective voltage regulator contributes serial voltage compensation. In this paper, voltage is compensated using two regulating principles namely voltage ratio regulation and polarity selection. The voltage regulator consists of a shell type transformer with multi windings which comprises two primary windings which are connected across the supply. The secondary winding acts as a compensating winding which is connected in to the input.

Discrete values of compensation can be achieved by changing the connection between the primary and secondary windings with three power contactors. A controller unit will compares the input voltage which has supplied to the domestic loads. This controller will compare input voltage value with the reference voltage. If compensation is necessary due to voltage fluctuations then controller will send a signal to the contactor. The contactors works in accordance with the controller unit.

The feature of the effective voltage regulator make it aptable for the needs of the long distance loads.

2.1 Step Voltage Regulation:
By using the technique of step voltage regulation, the voltage is to maintain the minimum input voltage at the consumer end. This process is done by using an auto transformer mechanism.

2.2 Sturdiness:
As the proposed voltage regulator design will be placed outdoor, at remote locations. So, the voltage regulator should be sturdy in nature, reliable and maintenance. Power contactors are used than power electronic devices to get high efficiency.

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2.3 Less Cost:

The voltage regulator requires less cost as we are using serial voltage compensation instead of power electronic devices and the efficiency increases even the size of the equipment is reduced.

In this paper we were discussing about single phase voltage regulator it could be extended for three phase networks.

III. POWER CIRCUIT

The power circuit of effective voltage regulator for single phase network comprises of a shell type multi winding transformer which consists of two primary windings and a secondary winding acts as a serial compensation winding . We have three power contactors which are used to connect the primary and secondary winding in the network. In this voltage regulator we can interconnect the two primaries in five different configurations. The required compensation step is performed by the control unit.

![Effective Voltage Regulator power circuit](image)

The two primary windings have same number of turns $N_p$, and they are connected to the input supply which is connected to the power contactor C3. The primaries can be series or parallel connected using contactor C1. So that the number of turns at the primary side would be $N_p$ or $2N_p$ every connection determines a certain voltage ratio as indicated in the table. The secondary winding acts as a serial compensation winding and it can be connected in series with the distribution network or bypassed using contactor C3.

The sequence of contactors C1, C2, C3 are given in the table

<table>
<thead>
<tr>
<th>C3</th>
<th>C1</th>
<th>C2</th>
<th>STEPS</th>
<th>CONNECTIONS</th>
<th>$K_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>O</td>
<td>O</td>
<td>4</td>
<td>P1+P2</td>
<td>$1 + \frac{N_s}{2 \cdot N_p}$</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>O</td>
<td>5</td>
<td>P1 // P2</td>
<td>$1 + \frac{N_s}{N_p}$</td>
</tr>
<tr>
<td>C</td>
<td>O</td>
<td>C</td>
<td>2</td>
<td>-(P1+P2)</td>
<td>$1 - \frac{N_s}{2 \cdot N_p}$</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
<td>1</td>
<td>-(P1 // P2)</td>
<td>$1 - \frac{N_s}{N_p}$</td>
</tr>
</tbody>
</table>

The output voltage $V_o$ can be determined by the input voltage $V_i$ and the compensation voltage $V_s$ which is divided by the regulator. The compensation voltage is given by the ratio of the secondary winding turns $N_s$ to the primary winding turns.
\( c^* Np \) the voltage at the input of the voltage regulation

\[ V_o = V_i + V_s = V_i + V_i * \left( \frac{N_s}{c^* N_p} \right) = K_c V_i \]

Where \( c \rightarrow \) ranges from 1 or 2

\( N_p \rightarrow \) Number of turns of primary windings

\( N_s \rightarrow \) Number of turns of secondary windings

This design of the voltage regulator has 5 different compensation steps. This can be done by changing the positions of the 3 power contactors. When the 3 power contactors are opened the standby mode is achieved, the device will be disconnected from the network and the secondary acts as short circuit. The loads connected are protected from the voltage regulator if any failure occurs in the system.

The rating of the voltage regulator depends on the rated power of the transformer \( S_t \) is lower than the power that the voltage regulator can supply \( S_{vr} \). The power difference depends on the ratio of the compensation need to be done and the rated voltage.

IV. CONTROL UNIT

The control system manages, commands, directs or regulates the behavior of the other devices or system using control loops. A control system is a unit which ensures the required response by controlling the output. Output can be controlled by varying the input mechanism.

In this paper the aim of the effective voltage regulator is to increase the line voltage and to ensure the system security in the event of a failure of the device or severe malfunctioning which is not predictable in the distribution network. At such situation the device will be automatically disconnected from the network. For this purpose a control unit is needed to monitor the regulator. We are using control unit for the system.

V. VOLTAGE REGULATION RESULT

The graph represents the voltage regulation which represents the input voltage on x-axis and output voltage on y-axis.

![Voltage Regulation Graph](image)

Fig. 2 voltage regulation waveforms with respect to input and output voltages

The regulation waveforms of the effective voltage regulator with respect to input and output voltages. The standard limits of the input voltage 230±7% are represented as dotted line. The regulation waveforms represents 5 steps of the various connections of the contactors C1, C2, C3.

In the step 1 the contactors C1, C2, C3 are closed position, the primaries are parallel with negative polarity and the input voltages \( V_r \) increases from 130 to 210 V which is in standard range of voltage.

In step 2 the contactor C3 is closed and C1 is opened and C2 is closed with these connection the primaries are series connected with negative polarity the input voltage increases from 150 to 230 V which is a standard range of voltage.

In step 3 all the three contactors are opened at this connection and the secondary acts as a short circuit no voltage is supplied to the line from the regulator the voltage range is between 190 to 230 V due to voltage sags.
In steps 4 and 5 the initial voltage increases and reaches the voltage which is very high, exceeds the standard limits of voltage range. So at this point voltage regulator corrects the voltage with two series steps path from B to C and C to D.

VI. SIMULATION DESIGN CONSIDERATIONS

6.1 Transformer Design

In this paper we preferred a shell type transformer because domestic loads have less rating of voltage and power so this shell type transformer is suitable for low voltage and low power rating applications. The ohmic losses are less due to the less requirement of conductor material and also core losses are less because half of the flux passes through the core. So overall efficiency of this transformer is high.

Here we have done the analysis and simulation for 230 V /40V transformer. So that this shell type transformer can give sufficient result for the entire operation. In order to reduce the energy losses, this transformer can design with low flux density

6.2 Standard Reference Voltage Range

Voltage amplitude is very important because loads can be defined within the specific limits only. So we need to maintain supply voltage constant. Otherwise voltage fluctuation will occur in the system then the system becomes unstable. For example requirement of voltage regulator at the loads are 230 ±7%. So that we can get minimum and maximum values like V up and V down. By maintaining these limits we can avoid oscillations and fluctuations in the device.

Whenever the output voltage is low, the control unit will send a signal to the contactors and the required amount of voltage is injected into the system and makes the system stable. To avoid oscillations the new reference voltage should always be lower than the reference voltage.

![Comparison of input voltages per day before and after compensation](image-url)
Fig. 4 The comparison of the voltage at load side before and after installing the effective voltage regulator per day.

Fig. 5. The simulation model of the effective voltage regulator for rural networks.

6.3 Compensation Switching Sequence

A compensator unit will change the position of the contactors of the device. The compensator unit starts from the closing of the contactor C3. The contactors C1 and C2 are opened or closed depending on the compensation step needed. The maintenance of this effective voltage regulator is very easy. The switching operation is performed off-load which reduces the transients and increases the life of contactors.

6.4 Switching Control

The life and strength of the voltage regulator is known by the power contactor C3 operates on-load. Immediate switching conditions will shorten the life of the contactor, and some malfunctioning can occur when the contactor open or close. Two poles of contactor C3 are connected parallel to show the load current remaining two poles are series connected to open the voltage.
6.5 Efficiency Test

The efficiency of the voltage regulator is maintained constant with respect to the change in power factor and the results and the voltage regulator ratings and input intake are mentioned keenly in the form of tables which are given below.
Table 2 Voltage Regulator Description

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Voltage</th>
<th>Current</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary P1</td>
<td>230V</td>
<td>6.52A</td>
<td>1500VA</td>
</tr>
<tr>
<td>Primary P2</td>
<td>230V</td>
<td>6.52A</td>
<td>1500VA</td>
</tr>
<tr>
<td>Secondary</td>
<td>40V</td>
<td>75A</td>
<td>3000VA</td>
</tr>
<tr>
<td>Non load losses</td>
<td></td>
<td></td>
<td>25.1 W</td>
</tr>
<tr>
<td>Load losses</td>
<td></td>
<td></td>
<td>104.1 W</td>
</tr>
<tr>
<td>Regulator step</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-40V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-20V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>+20V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>+40V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Efficiency (%) at power factor 1

<table>
<thead>
<tr>
<th>Load (per Unit)</th>
<th>0.25</th>
<th>0.50</th>
<th>0.75</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>98.86</td>
<td>99.10</td>
<td>99.15</td>
<td>99.08</td>
</tr>
<tr>
<td>Step 2</td>
<td>99.42</td>
<td>99.47</td>
<td>99.39</td>
<td>99.27</td>
</tr>
<tr>
<td>Step 4</td>
<td>99.54</td>
<td>99.35</td>
<td>99.31</td>
<td>99.21</td>
</tr>
<tr>
<td>Step 5</td>
<td>99.17</td>
<td>99.17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8. The efficiency maintained with respect to time in a day

VII. CONCLUSION

This paper shows an effective voltage regulator and it is designed for domestic loads. The main aim of this project is to maintain the voltage and power within the permissible limits without any oscillations. By using different compensating steps with the help of contactors and circuit breakers. So that equipment becomes more reliable.

This effective voltage regulator has the properties like hardiness, less cost and less maintenance these characteristics can satisfy the domestic loads the advantage of effective voltage regulator is given below.
A. This proposed voltage regulator rated power depends upon the maximum supply voltage and the desired compensated voltage from the consumers. In this paper we have used 230/40V transformer. It gives more and effective efficiency as compared to the conventional voltage regulator.

B. In rural areas we cannot attain accurate voltage compensation because of long duration voltage variations. It provides serial voltage compensation in case of requirement.

C. By using five distinct compensating steps the control unit will select the contactors and compensate the voltage without using the power electronic devices.

D. This voltage regulator has less maintenance and durability is high as compared to the power electronic based voltage regulators.

E. This device is automatically disconnected from the line in case of any fault condition or malfunction by this property it gives more reliability.

We have done this project by simulation and programming which gives effective results for the whole operation and it represents high efficiency, reliability and power quality improvement.

ACKNOWLEDGMENT

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