Research on the Functioning of Static Devices for Continuous Voltage Regulation

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Abstract – **This paper aims to present some generalities on the continuous adjustment of voltage and its importance in the power system and some laboratory work. It also presents an assembly made by the author after an electrical scheme of principle that is part of the current stage of technique, some experimental data obtained and a number of conclusions.**

Index Terms – **continuous regulation, premagnetization, static device, transducer, transformer.**

I. INTRODUCTION

The technical progress and the developing of the modern power systems led to the increase of the number and of the value of electrical power requested by the consumers whose operations is influenced by the supply voltage. These influences consist in the need of voltage regulation between wide limits, with special requirements regarding refinement and precision regulation, but also to maintain constant voltage.

But there are some installations that require rigorously constant voltage supply, such as electronic computing equipment, industrial automation equipment, medical installations.

So the realization of devices for adjusting the voltage is an important task and at the same time complex because of implications of practical and theoretical.

Ensuring the quality of electricity supplied to domestic consumers and the industry alike, is in fact keeping constant both the frequency and amount of voltage that reaches them.

Related to those specified above should be noted that the worsening quality of electricity through an inadequate frequency or low voltage at the receiving side effect is the occurrence of negative consequences that ultimately determines significant damage.

The frequency of the voltage supplied to consumers depends on the active power and indicate, in an interconnected network, the balance between the amount of active power produced and "pumped" into the power and the active power consumed by receivers.

Unlike the frequency, the voltage depends on reactive power and indicates the balance between the amount of reactive energy produced and the amount of reactive power consumed.

Maintaining a constant frequency is relatively simple and can be done in a centralized way because, in an interconnected system, the frequency is the same in all system nodes. Problems arise with regard to the tension because it has different values in different points of the system due to voltage drop in the network. These falls of voltage are variable and depend on the powers transported, so that if they maintain a constant voltage at different points system, in other points it limits vary inadmissible.

Keeping to the required voltage becomes a problem of each sector network. Therefore, the voltage regulation problem is quite complicated and is solved in modern power systems through a series of measures. Although it talks about maintaining a constant voltage rigorous, practical, this is not possible and tries to maintain voltage variations in the allowable limits.

II. THE ACTUAL TECHNICAL STAGE

In the field of continuous voltage regulation are known several methods classified according to the devices used as follows:

- continuous regulating devices with sliding contact;
- continuous regulating devices with relative movement of windings;
- devices for voltage regulation, which combines features of the two categories mentioned anterior;
- Static devices for continuous voltage regulation.

Also the solutions used for continuously adjust the voltage using *sliding contacts* are classified as follows:

- transformers and autotransformers with roller contact;
- transformers and autotransformers with stepping contacts;
- Transformers and autotransformers with the sliding contact permanently following the spiral track of the secondary coil (considered fixed).

In the category of continuous regulating devices with *relative movement of windings* we have:

- induction regulator;
- transformer with moving coils without intermediate windings;
- transformer with axial moving coils;
- transformer with short-circuited mobile coil;
- Transformer with voltage regulation by changing the magnetic coupling between primary and secondary winding.

The mixed devices for voltage regulation, which combines features of the two categories mentioned anterior are classified as follows:

- transformer with secondary rotating coil with air gap (Thoma);
- transformer with secondary rotating coil without air gap.

The static devices realize a continuous and fine adjustment of voltage and are based on the use transducers (magnetic amplifiers).

The voltage regulating devices based on transducers are characterized by a great security while functioning and a high speed adjustment.

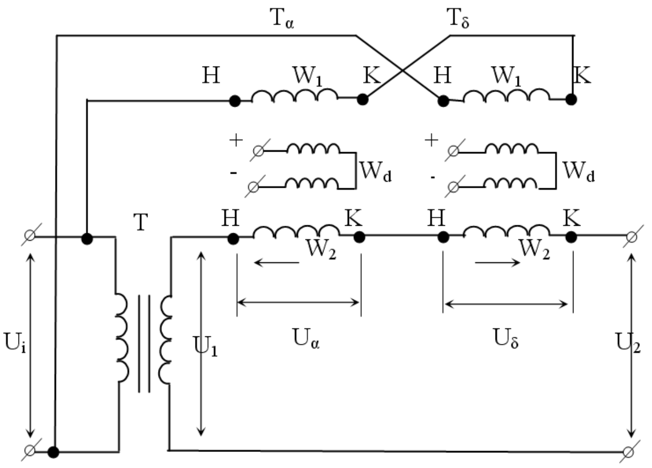


Fig. 1 Device operating on the principle of overvoltage transformers with premagnetization (reproduced from [5])

In [5] it is described a device for smooth voltage adjustment that operates on the principle of overvoltage transformers with premagnetization. The device layout is shown in Fig. 1.

The non-adjustable transformer T have connected in the output circuit two additional transformers with premagnetization T_α and T_δ, linked in series with the consumer. Additional transformers are identical and have primary windings W_1 connected in series and charged from the supply voltage U_1. Since the primary windings W_1 of the auxiliary transformers are connected with reversed polarity, secondary voltages U_α and U_δ will be contrary. The value of U_α and U_δ is adjusted using the premagnetization coils W_d. The adjusted voltage U_2, which is obtained out of the device is equal to the sum of principal voltages U_α and U_δ, the first of which act in opposition and the second in phase with the voltage U_1.

The adjustment is achieved by differential premagnetization of the transformer T_α şi T_δ, which is obtained by modifying the continuous current from the w_d windings. When we increase the demagnetization current in one of the transformers it decrease in the other one and vice versa.

The average voltage U_2 is equal to the voltage U_1 and is obtained at an equal premagnetization of the two additional transformers. Maximum voltage U_2 is obtained when we completely premagnetizate T_α transformer and reduce to zero the T_δ transformer's. In this case, the voltage U_α, which is in opposition to U_1 has a negligible value, while U_δ tension that is adding to U_1 has its maximum value. Reversely, the minimum voltage U_2 is obtained when the premagnetization of the transformer T_α is reduced to zero and the transformer T_δ is complete premagnetizated.

Improvement of the technical-economic indicators in voltage stabilizers without contact is made using, as main elements of implementation, three phase autotransformers, adjustable by redistributing the voltage (ATRRT).

This type of transformer also presented in [1], consists of two α and β autotransformers downward and lifter linked in series; the windings of these autotransformers are placed on two cores with a common yoke.

The supplementary magnetization windings are placed inside the primary windings, supplied with alternating current. This type of construction, in case of independent supplementary magnetization of the core's columns, provides the possibility to adjust the voltage on each phase.

During the supplementary magnetization, successive, of the transformers cores, both downward and lifter, the coefficient of transformation may vary.

The use of transformers for continuous adjustment of the voltage in the test facility with an alternating voltage has the disadvantage that the voltage provided by these transformers is affected by variations in voltage industrial network that is coupled to the transformer.

To remove this problem the Brentford Electric Company made a special transformer for voltage static stability with high-speed for single-phase circuits.

Known as "SINUSTAT", the device has a three arms core, like the one of a three phase transformer, with a primary and a secondary coil (Fig. 2).

Supply is connected across the primary coil of the central arm. The three primary involution are connected so that the primary winding of the outer arms are in series with one another in the cross with power and in parallel with involution of the primary middle arm. Each primary involution has the same number of coiling. Secondary winding are connected in series, coils on each arm are different, according to the range of voltage and nominal voltage stabilizer especially.

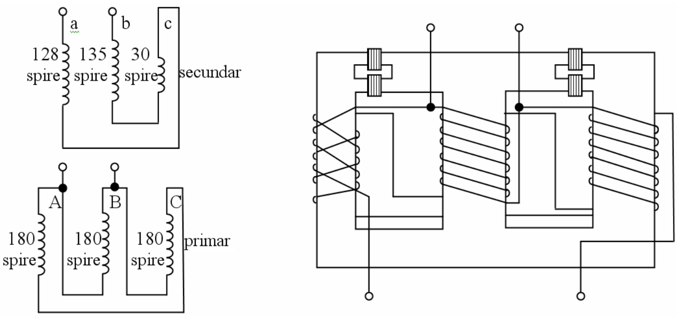


Fig. 2 SINUSTAT Transformer (reproduced by [3])

At the top of the magnetic yoke two windows are cut further, the middle arm and outer arms and at the two sides of each window there is placed a control winding.

These windings are supplied with continuous current to vary the main flow from the outer arm of the core. To prevent the induction of an alternating current in the winding on each of the two windows is reels also a short-circuited compensation involution with the same polarity on each side, so that the induced electromotive force is canceled. As shown in Fig. 2, winding control and compensation are on the same bobbin winder.

If there is current in both the control winding, magnetic flow is divided equally between the two outer cores, so that the coils voltage, induced into exterior windings is half of the voltage of the central core.

In our example, with a 240 V power supply, the central core has 1.33 V/coil, and the side cores have 0.66 V/coil. All the secondary voltage values have same polarity and cumulated we have 283.5 V. When we have a big enough continuous current through the control winding, the core in that point is saturated and the alternative flux can't pass through the side arm to this side of the core.

Effectively, the primary involution on an arm, say arm A will be short-circuited and the primary windings B and C will be in parallel, both with 1.33 V / spire. Total secondary voltage now becomes 219V. If the core placed on the C arm it's saturated in the same manner the secondary voltage is 349 V.

Since the currents variations in those two control windings in proportion are controlling the flux distribution between the side arms, it can be realized an output stabilized voltage for a properly input voltage domain.

Since, under load, the primary and secondary coils are balanced on the central core, the primary current on the B core will be, for example, 15 A, for a secondary current, of 20 A.

The side arms supports a unbalanced state on the primary and secondary coils, providing some saturation effects that cause the circulation of an third harmonic flux.

To cancel this harmonic a winding is connected with the A arm and a third harmonica filter.

The stabilizers are double winder so that they can provide a level of processing power and can isolate the load power.

Output wave form is excellent, stabilizer being unaffected by normal variations in frequency. Stabilizing output voltage to ± 0.5% is standard, but can be obtained and ± 0.25% for special purposes. At a load linear distortion of output wave form is less than 3%. Power factor is better than 0,8 and the yield is over 80%. Stability is achieved in several periods. After the presented principle three phase transformers were realized with the same purpose as the described transformer.

III. EXPERIMENTAL DATA

In the static testing device for voltage adjustment we used the diagram below, with the following data:

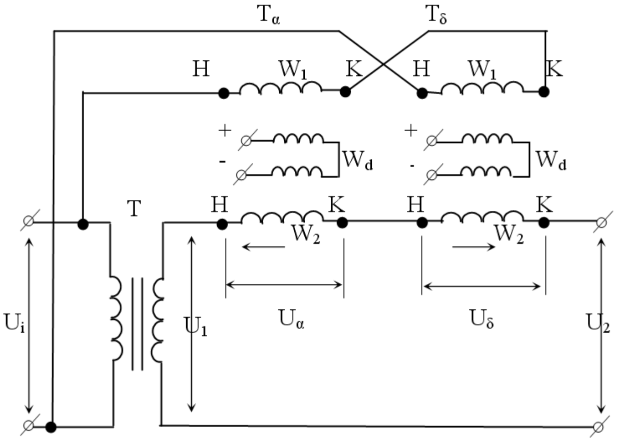


Fig. 3 Scheme used, (reproduced from [3])

$W_1 = W_2 = 717$ spires, where W_1, W_2 are the number of spires from secondary and primary windings of the premagnetization transformers.

Φ=0,18 mm, represents diameter of the copper conductor used to the two transformers winding.

$W_p = W_s = 715$ spires are the number of spires for the primary winding, respectively secondary of the T transformer, whose voltage is being adjusted.

Φ_T=0,18 mm, represents diameter of the copper conductor used to winder the T transformer windings.

$W_d = 6300$ spire, is the number of spires used for the premagnetization winding, supplied with continuous current.

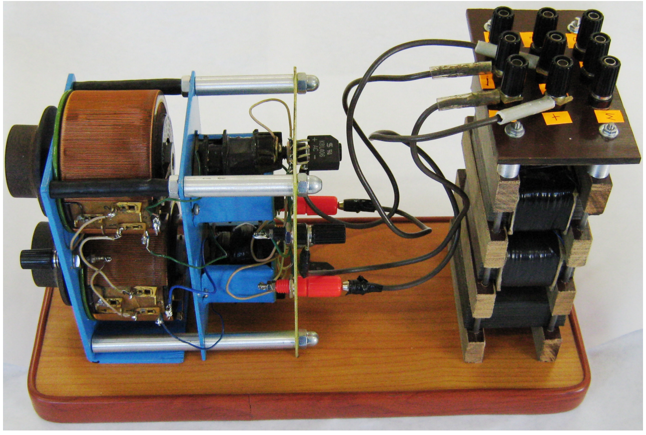


Fig. 4 Static device used

After adjusting the voltage some data were obtained and used for making the following graphs:

- in one of the case, we premagnetizated the first auxiliary transformer:

TABLE I. DATA FOR THE FIRST CASE

Ucc[V]	**Uca[V]**		
0,12	54,5	18,06	9,75
1	45,68	19,39	9,109
1,206	43,12	20,4	8,676
1,475	40,22	21,59	8,239
1,66	38,3	22,79	7,834
2,1	34,65	23,49	7,647
2,28	33,3	25,24	7,185
3,04	28,8	27,4	6,704
3,58	26,66	28,86	6,374
4,09	24,88	30,48	6,072
5,12	22,17	33,51	5,642
6,04	20,39	35,29	5,408
7,13	18,56	37,42	5,195
8,07	17,43	39,54	5,016
9,12	16,22	41,84	4,857
10	15,37	44,28	4,722
11,01	14,46	48,34	4,562
12,15	13,54	50,58	4,486
13,31	12,68	56,02	4,396
14,03	12,21	60,16	4,357
15,08	11,54	65,61	4,323
16,62	10,65	68,62	4,308

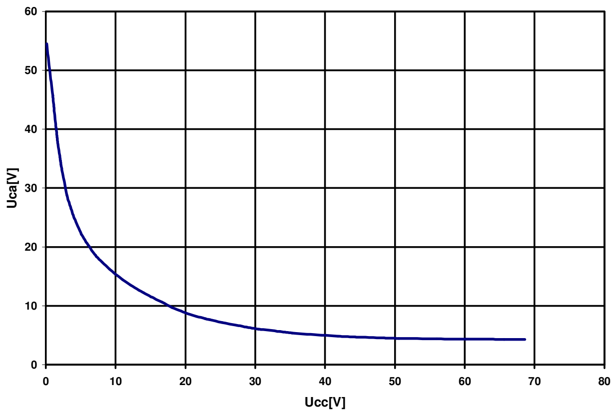


Fig. 5 The adjusted ,Uca, voltage depending on the remagnetization voltage, Ucc, in the case of the first transformer premagnetization

- in the next case, we premagnetizated the second auxiliary transformer:

TABLE II. DATA FOR THE SECOND CASE

Ucc[V]	Uca[V]		
0,13	54,39	14,89	91,75
1,019	63,07	16,38	92,33
1,258	66,14	18,21	92,64
1,462	68,32	20,16	93,14
1,695	70,21	22,62	93,64
1,911	71,85	23,31	93,81
2,233	73,81	25,62	94,21
2,567	75,68	27,71	94,41
3,078	78,01	30,63	94,78
3,59	80,08	33,71	95,3
4,078	81,31	36,64	95,67
5,095	83,8	38,91	95,78
6,109	85,66	41,88	96,05
7,442	87,28	45,67	96,42
8,29	88,15	50,17	96,5
9,268	88,91	56,38	96,58
10,44	89,65	59,94	96,78
11,41	90,12	66,46	97,02
12,4	90,68	70,20	97,18
13,57	91,29	74,35	97,45

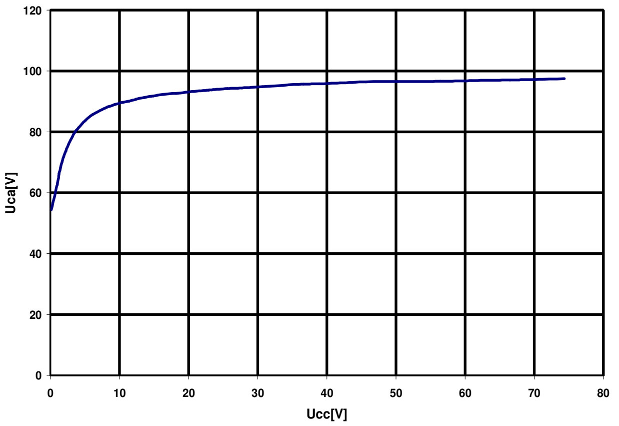
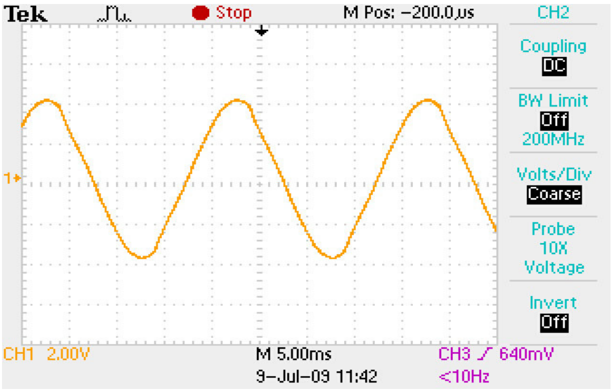
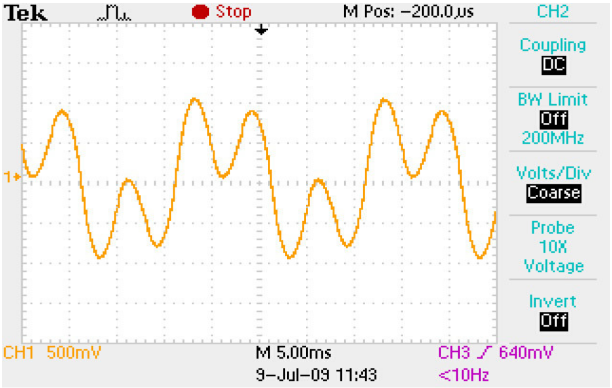


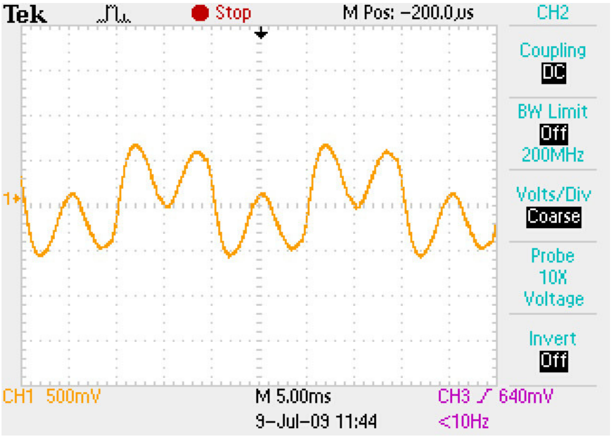
Fig. 6 The adjusted ,Uca, voltage depending on the premagnetization voltage, Ucc, in the case of the second transformer premagnetization

We also obtained a series of oscillograms of the output voltage both at increasing the voltage and decreasing as follows:

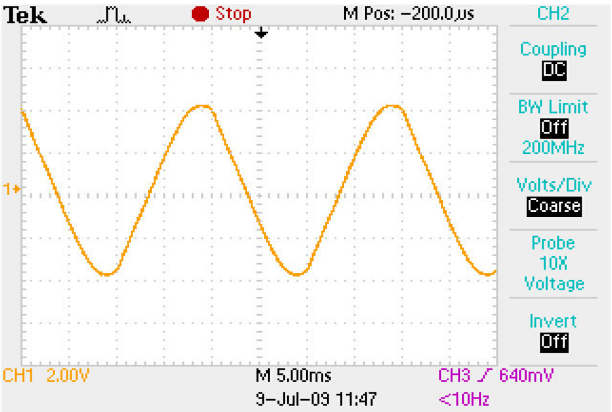
- we adjust the output voltage between 57,5 V and 4,308 V:

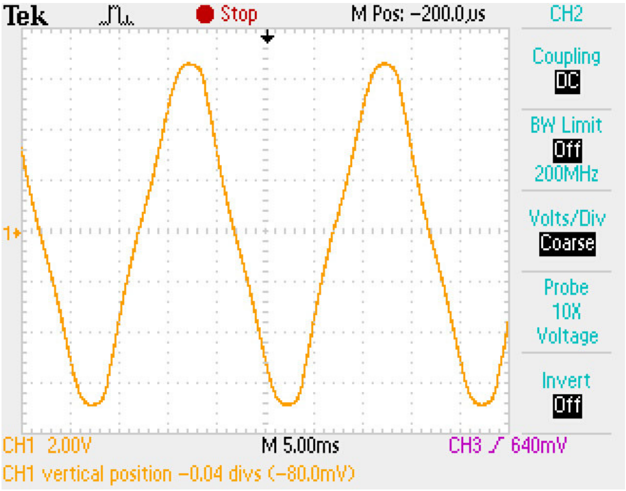


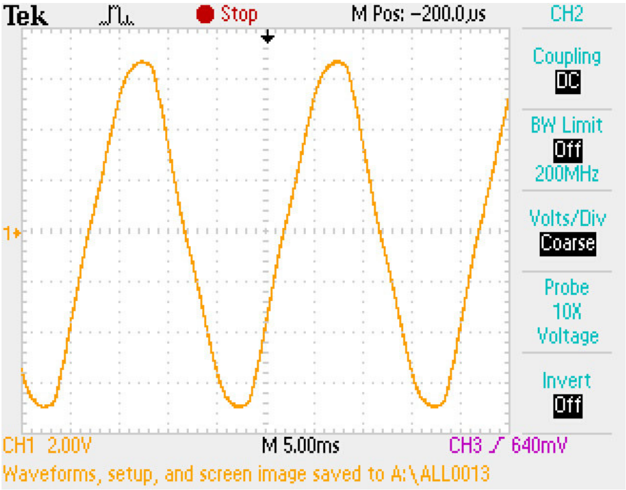




- we also adjust the voltage between 54,29 V and 97,45 V:







It can be seen from the data we have developed that we adjust the voltage between 4.308 ÷ V 97.45 V with a supply voltage of the transformer T equal to 50 V. We therefore made a voltage regulation between 8,616 % and 194,9 % from the input voltage.

It is easily to notice that by increasing the continuous voltage of the premagnetization windings above the 40 V DC, the voltage value that is adjusted upwards or downwards change very little.

IV. AREAS OF USE

Fine and precise adjustment of the supply voltage limits it is necessary in the following areas:

- test facilities for power equipment;
- electrical installations, particularly with asynchronous motors in various branches of industry such as, textile industry, paper industry;
- the power system;
- electricity transport and distribution.

Static devices for voltage regulation can be used in some laboratory work to verify the rigidity of the dielectric insulation of transformers.

V. CONCLUSION

For continuously voltage adjustment there are known several ways classified under 4 important categories as follows:

- continuous regulating devices with sliding contact;
- continuous regulating devices with relative movement of windings;
- devices for voltage regulation, which combines features of the two categories mentioned anterior;
- static devices for continuous voltage regulation.

Currently the most widespread method of voltage adjustment is to adjust voltage in steps by using plugs with transformers switch under load.

Methods of voltage regulation are continuously reviewed and improved to be used in various applications such as:

- test facilities for power equipment;
- electrical installations, particularly with asynchronous motors in various branches of industry such as, textile industry, paper industry;
- the power system;
- electricity transport and distribution.

The static voltage adjustment presents several advantages, among which the most important are:

- allowing a linear voltage adjustment;
- having a high reliability due to lack of parts in motion.

After experimenting the voltage regulation with this static device we obtained a voltage adjustment between 4,308 V÷97,45 V, having a supply voltage of the T transformer equal to 50 V. Therefore we achieved a voltage regulation between 8,616 % and 194,9 % from the input voltage.

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