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DESIGN AND CONSTRUCTION OF A MULTI-ACTION POWER TRANSFORMER WITH AN IN-BUILT SEALER

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Abstract: **This Research paper, contains the design and construction of a multi-action power transformer which in addition to its dual purpose of both stepping-up and stepping-down voltages, also performs sealing and cutting functions using the inductance/resistance heating principle. The multi-action power transformer is a three-in-one device that uses the principle of mutual inductance for its operation. It contains a primary winding, and two secondary windings with three outputs all depending on a common input supply to provide a step-up voltage of the range 220 V – 240 V and step-down voltages of the range 90 V – 110 V and 25 V – 50 V respectively. The device when tested with household electronic with 220V – 240V specification, functioned for all input voltages within 100 V – 180V range. Below 100V, the output was observed to be too low (< 135 V) and above 180V, the output was observed to be too high for use (>240 V). For household electronics with 110V specification, the device functioned well for input voltage range 220 V – 170V. Below 170V, the voltage was observed to be low (<85 V) and above 220 V, the output was observed to be too high (>110 V). The Sealing outlet however worked well for a wide range of voltages, 10V – 240V. The device, is highly effective for provision of standard voltages for commonly used household electrical equipment, polythene sealing for petty traders as well as provision of amplified voltage to be utilized by automatic voltage regulators.**

Keywords**: power transformer, mutual inductance, primary winding, inductance heating.**

Abbreviations:

N_s; number or turns in secondary winding, $Np_;$ number of turns in primary winding, $V_{s;}$ potential difference across secondary winding, V_p; potential difference across primary winding.

I. BACKGROUND

The role of electricity world over as the single, major and most important driven factor for technological development and advancement cannot be overemphasized. The extremely poor provision of this all important commodity has been the most important factor dwindling overall development thereby guaranteeing poverty among the majority of the Nigerian population. The challenges associated with electricity provision in Nigeria is not only its unavailability but also its ineffectiveness during its seldom availability. The voltage is usually painfully acute especially in rural areas. Low voltage which is not even sufficient to power an automatic voltage regulator is a common experience in most rural dwellings in Nigeria for the past couple of decades. In order to make-up for this inefficiency, the rural dwellers usually resort to the dangerous practice combining two high tension phases to power their homes which sometimes result into damage in electrical appliances of outright electrically triggered fire outbreaks.

The multi-action-power transformer is designed to amplify (in the case of the step-up phase) the input voltage irrespective of it magnitude. This amplified voltage can be used directly with appliances or fed to an automatic voltage regulator for regulation. The multi-action-power transformer sealing/cutting circuit makes it possible for polythene sealing/cutting function for voltages as low as 100 V and as high as 230 V.

II. REVIEW OF LITERATURE

A transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits. A varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic flux through the secondary winding. This varying magnetic flux induces a varying electromotive force (emf) or voltage in the secondary winding. Transformers can be used to vary the relative voltage of circuits or isolate them, or both. Transformers are essential for the transmission, distribution, and utilization of electrical energy (Wikipedia).

In their work Design and Construction of a 4 KVA Automatic Voltage Regulator with Surge Protector, Omajugba and Adeloye(2004) designed and constructed a device primarily to solve the problem of poor unstable power supply form the electricity supply authority owing to the fact that unduly low or high voltage has caused a lot of havoc to electrical equipment.

In their work, Rasheed and Lateef (2005), observed that nylon has served as succor in the packaging of goods for decades little does one wonder why there has been tremendous progress in the nylon sealing machine from the energy consuming manual type to the less tedious automatic impulse expending of the automatic sealer. He used a photo cell and an electromagnet to achieve the automatic action. The machine was adequate for both small and large-scale, nylon sealing use, and was both efficient and reliable.

Omajugba and Adeloye(2004), adopted the principle of tapped auto-transformer with two ideal windings to perform the regulating functions. The output load is switched to the appropriating taping by the tap changer. The tap-changer consists of interconnected relays to perform the switching function. A control circuit has been designed to actuate the tap – changer automatically for a much more advanced sealing machine with the capacity of sealing/cutting 800 nylon/hour, a transformer with 1000 turns of wire for the secondary and about 1200 turns for the primary is required with approximately $27 USD fabrication cost (www.projectstoc.com)

For small transformers, resistance heating by injection of current into the windings is used. The heating can be controlled very well, and it is energy efficient. The method is called low-frequency heating (LFH) since the current is injected at a much lower frequency than the nominal of the power grid, which is normally 50 or 60 Hz. A lower frequency reduces the effect of the inductance in the transformer, so the voltage needed to induce the current can be reduced (Fink and Beatty, 1978)

Aim and Objective:

To build a multi action power transformer with a sealer that can accommodate voltage of the range 0-260V and frequency of up to 25% above the normal operating frequency.

Limitations:

- The multi-action-power transformer is only necessary where electricity supply is 180 volt or less.
- In order not to have a limited input range, this device does not control voltage surge.

III. DESIGN AND METHODOLOGY

Block Description:

Like every other basic transformer, the design procedure of multi-action transformer is a very simple one depending largely on local material that can easily be collected in any average market. This chapter explains how these materials are easily coupled to obtain the structural framework and the principal operational parts of the machine.

The Materials:

The materials used in the design and construction of multi-action power transformer includes, masking tape, wooden box, connecting wires, soft iron core, paper, on/off switches, plugs sockets, pure cotton textile, nails, wood, resistance wire, coated copper wires, variable a.c. source and voltmeters.

- Masking tape: This is used to insulate the terminals for prevention of shock and spark in case of contact with a neighboring naked wire;
- Wooden box: This provides the casing of the multi-action power transformer which is the external framework and protects the components of the multi-power transformer form dirt, moisture and mechanical damage.

Calculation for Turns Ratio:

Table 1: summary for volt/turn ratio calculations

S/NO	V_s (volts)	V_p (volts)	N_p (turns)	N_s =(N_p/V_p) * N_s (turns)
1	50	170	400	117.6471
2	110	170	400	258.8235
3	230	170	400	541.1765

Dimensions:

- Size of wire used in primary is 0.83mm and 1.82mm thick.
- Size of wire used in secondary is 0.84mm and 1.9mm thick
- The thickness and length of sealer wire used is 0.4mm and 250mm respectively
- The size of the wood used as seal plane is 39×30cm.

IV. CONSTRUCTION

Table 2: Materials and Specification

Materials	Specification	Quantity
(1) Wire used in primary coil	40 S W G	20m
(2) Wire used in secondary coil	20 S W G	24m
(3) Casing	Ply wood	(20 x 39) 5mm
(4) Soft iron core	Fridge compressors	3
(5) Lamination material	Cotton textile	¼ yard
(6) Plug	10 Amplifier, 250v	2
(7) Wire	Flexible (sun rise wire and cable)	1 yard
(8) Socket	Mild coated with zinc	2
(9) Sealers	Nickelcrome	250mm

Core Assembling:

Three uniform shell-type soft iron cores of the type used in fridge compressors are used for design. Each layer of the core is made up of a round shape metal with four narrow holes at its edges. These holes are buttoned together with the aid of a coated copper wore across three soft iron cores to form single core, which are three cores assembled firmly together. The assembled cores are then laminated using bunch of pure cotton textile material. as presented in Figure 1.

Figure 1: orientation for core assembling

Systemic windings:

The multi-action power transformer is constructed with three coils or windings, which were wrapped (using right hand winding method) round the laminated soft iron core as presented in Figure 2.

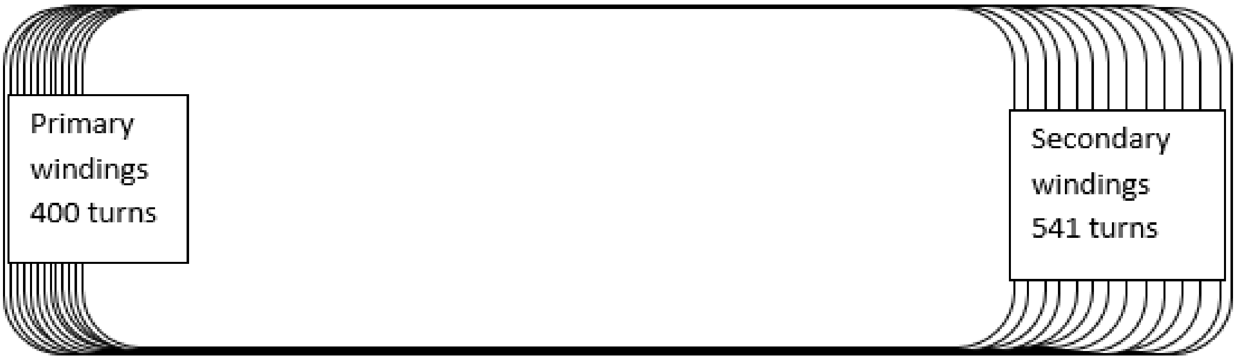

Figure 2: laminated core primary and secondary windings

Two lengthy properly coated copper wires 0.83mm and 1.82mm thick were used for primary and secondary windings respectively. The multi-action power transformer has one primary and two secondary windings. The primary windings have 400 turns. While the secondary windings are of 118 turns and 259 turns respectively. The constructed multi-action transformer has a total of 541 turns. The secondary turn with 118 turns of windings is center tapped.

External Framework Construction:

The external framework is a network of plywood connected perpendicularly to each other and held firmly in place by nailing them together. The box is rectangular in shape comprising of eight-polished plane for beautification. The external framework surfaces and attachments are presented in Figure 3.

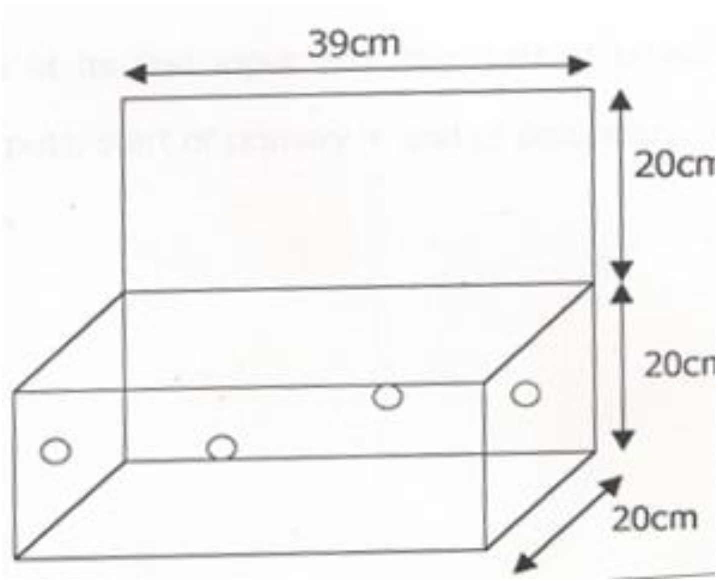

Figure 3: uncoupled and coupled casing for the device

This external framework is to protect the major component of the transformer from dirt, moisture and mechanical damage.

Winding-Outlet Connections:

The multi-action power transformer has a total of three outlets (output) and 9 sources input. The input if form the a.c. source, which is about 220V under normal condition. The three outputs comprise of a step up output phase of 220V-300V and two step down phases of 90V-110V and 25V-50 volts respectively.

The 25V-50V phase and 90V -110V phase share the main a.c. source as their input with the beginning of secondary and the centre tap (at 118 turns) as output for the lower volt phase. The higher step down phase has its output as the beginning and end of the total secondary 259 turns. While for the step up connection, end of primary + start of secondary stands at its first input with the start of primary as its second input. It equally has two outputs, start of primary + end of secondary. The circuit connection details is presented in Figure 4.

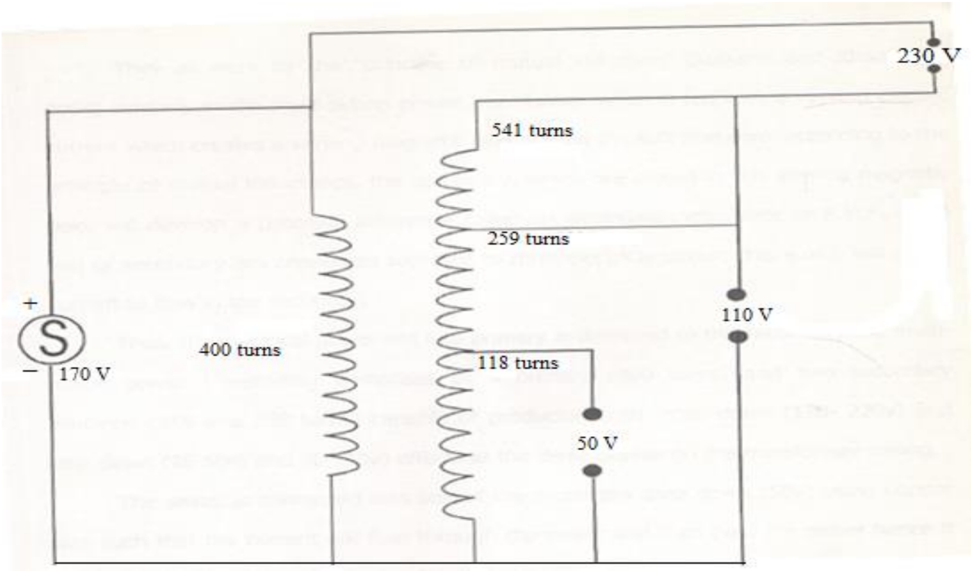

Figure 4: multi-action power transformer circuit

V. MODE OF OPERATION

Basically the transformer consists of primary and secondary windings, which are electrically separated from one another, but magnetically linked to each other. They all work by the principle of mutual induction. In the multi-action power transformer, when the core is fed with a varying electric current which creates a varying magnetic field around the soft iron core, the secondary, which is placed in this varying magnetic field, will develop a potential difference called an electromagnetic force. If the end of secondary are connected together to form electrical circuit, this e.m.f. will cause current to flow in the secondary.

Thus the electrical power fed into primary is delivered to the secondary. The multi-action power transformer comprises of a primary (400 turns) and two secondary windings (118 and 259 turns) capable of producing both step up (220-230V) and step down (25-50V and 90-110V) effects at the three outlets on the transformer casing.

The sealer is connected into one of the secondary step down (50V) using copper wire such that the current will flow through the sealing wire making it red-hot, hence it can be used for sealing/cutting operation.

Table 3: Step-Up Phase (220-240 V)

S/N	a.c. Input Supply (V)	Out Put Results (V)				Validity
		1st	2nd	3rd	Average	
1	100	135	130	140	135	Partially Valid
2	110	147	145	150	147	Partially Valid
3	120	160	165	166	163	Partially Valid
4	130	174	175	180	176	Partially Valid
5	140	180	187	190	185	Partially Valid
6	150	195	200	200	198	Partially Valid
7	160	205	210	215	210	Partially Valid
8	170	219	220	228	222	Valid
9	180	235	232	238	235	Valid
10	190	245	244	257	249	Invalid
11	200	255	255	260	257	Invalid
12	210	260	260	260	260	Invalid
13	220	280	282	279	280	Invalid
14	230	293	292	\294	263	Invalid
15	240	306	306	306	306	Invalid

Table 4: Step-Down Phase (90-110 V)

S/N	a.c. Input Supply (V)	Out Put Results (V)				Validity
		1st	2nd	3rd	Average	
1	100	63	63	63	63	Partially Valid
2	110	66	66	66	66	Partially Valid
3	120	70	70	70	70	Partially Valid
4	130	74	74	74	74	Partially Valid
5	140	79	79	79	79	Partially Valid
6	150	82	82	82	82	Partially Valid
7	160	85	85	85	85	Partially Valid
8	170	90	90	90	90	Valid
9	180	94	94	94	94	Valid
10	190	99	99	99	99	Valid
11	200	101	101	101	101	Valid
12	210	105	105	105	105	Valid
13	220	110	110	110	110	Valid
14	230	113	113	\113	113	Invalid
15	240	117	116	118	117	Invalid

Table 5: Step-Down Phase (25 V-50 V)

S/N	a.c. Input Supply (V)	Out Put Results (V)				Validity
		1st	2nd	3rd	Average	
1	100	25	25	25	25	Valid
2	110	27	27	27	27	Valid
3	120	30	30	30	30	Valid
4	130	31	31	31	31	Valid
5	140	34	34	34	34	Valid
6	150	35	35	35	35	Valid
7	160	37	37	37	37	Valid
8	170	39	39	39	39	Valid
9	180	40	40	40	40	Valid
10	190	43	43	43	43	Valid
11	200	45	45	45	45	Valid
12	210	46	46	46	46	Valid
13	220	49	49	49	49	Valid
14	230	50	50	\50	50	Valid
15	240	52	52	52	52	Invalid

VI. RELIABILITY TEST

Reliability is the characteristic of an item expressed as the probability that it will perform a required function under stated condition for a stated period of time.

Basic Assessed Failure Rates:

(C) Probability failure for capacity = 0.01

(IH) Probability failure for cable = 0.2

(SW) Probability failure for Switch = 0.01

(I) Probability failure for coil = 0.01

VII. CONCLUSION

According to the results, it can be concluded that the aim of the work was achieved, a multi-action power transformer with 88% efficiency was built and when tested with household electronic of 220V – 240V specification, it functioned for all input voltages within 100V – 180V range. Below 100V, the output was observed to be too low (< 135V) and above

180V, the output was observed to be too high for use (>240V). For household electronics with 110V specification, the device functioned well for input voltage range 220V – 170V. Below 170V, the voltage was observed to be low (<85V) and above 220V, the output was observed to be too high (>110). The Sealing outlet however worked well for a wide range of voltages, 10V – 240V it however performed the sealing/cutting operation with the aid of resistance wire connected across its lowest step-down output phase.

VIII. RECOMMENDATION

Because of its effectiveness in voltage multiplication and low input voltage dependency for sealing/cutting functions, this power enhancement device should be utilized by rural dwellers in places with acute power supply instead of the hitherto dangerous practice of combining two phases of power line.

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