(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 671 777 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**24.06.2020 Bulletin 2020/26**

(51) Int Cl.:
***H01F 41/02*** *(2006.01)* ***H01F 41/04*** *(2006.01)*

(21) Application number: **18214677.9**

(22) Date of filing: **20.12.2018**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**KH MA MD TN**

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(54) **METHOD OF PRODUCING PARTS OF A TRANSFORMER**

(57) The present invention relates to a method of producing parts of a low, medium or high voltage transformer. The method comprises:
providing a set of parameters for at least one internal part or insulating body of a transformer to be located at a customer's site;
sending at least one instruction order to one or more additive manufacturing printers, wherein the at least one instruction order is based on the set of parameters;
producing by the one or more additive manufacturing printers the at least one internal part or the insulating body, the production comprising utilisation of the set at least one instruction order; and
providing quality information on the manufactured at least one internal part or the insulating body.

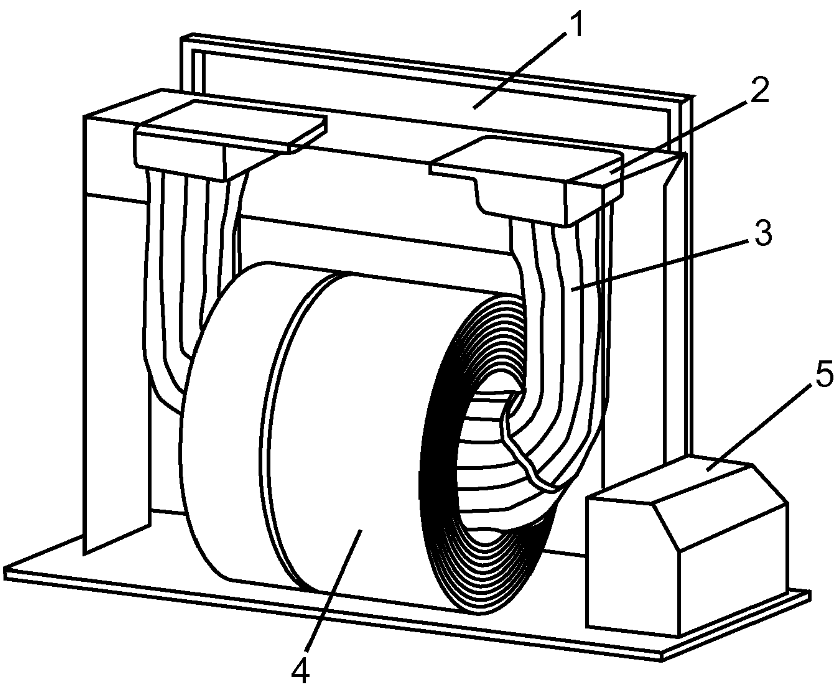


Fig.1

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## Description

FIELD OF THE INVENTION

**[0001]** The present invention relates to a method of producing parts of a transformer, and a transformer having at least one internal part or insulating body produced using such a method.

BACKGROUND OF THE INVENTION

**[0002]** As an example, medium voltage (MV) voltage transformers and medium voltage (MV) current transformers form parts of an electric substation used in electrical generation and distribution. A design of a MV transformer using conventional components needs to reflect the possibility for manufacturing deviation, and the possibility to assemble various parts and also the need to subsequently embed (for example via casting) those parts within an insulating material. All these items result in the need to provide some space margin, which can limit the performance of a MV transformer such as a power transformer or instrument transformer.
Furthermore, parameters for medium voltage transformers are often settled late in a new design process, but customers require short delivery timescales. Once all components parameters are clarified, components need to be quoted and purchased. The transport time adds into total delivery time of such components. Assembly of various parts is then carried out once parts are available. Production of components is done at manufacturer premises and tested. Once manufactured and assembled, the part or product is packed and sent to the customer for assembly of a medium voltage transformer. Thus, a MV transformer has numerous components or parts, with parameters defined at this component level. As such, it can be difficult to achieve short delivery timescales for components when replacement is required or when a new MV transformer is being commissioned, or when updated parts with new parameters are required. Similarly, in the case of missing spare parts, these need to be ordered, produced and delivered, resulting in a long delivery time. This situation is exacerbated because such parts or components are not usually held in stock. Part production can take several months, as the production process can involve several suppliers/manufacturers with a number of manual assembly operations dependent on each other. This combined with the necessary transport of semi-fabricated and/or semi-assembled goods and transport to the final customer also leads to further delivery prolonged delivery timescales.
The above also applies to low and high-voltage transformers.

**[0003]** There is a need to address this issue.

SUMMARY OF THE INVENTION

**[0004]** Therefore, it would be advantageous to have means to improve the production of parts of a transformer.
The object of the present invention is solved with the subject matter of the independent claims, wherein further embodiments are incorporated in the dependent claims.

**[0005]** In a first aspect, there is provided a method of producing parts of a low, medium or high voltage transformer, the method comprising:

a) providing a set of parameters for at least one internal part or insulating body of a transformer to be located at a customer's site;
e) sending at least one instruction order to one or more additive manufacturing printers, wherein the at least one instruction order is based on the set of parameters;
f) producing by the one or more additive manufacturing printers the at least one internal part or the insulating body, the production comprising utilisation of the set at least one instruction order; and
g) providing quality information on the manufactured at least one internal part or the insulating body.

**[0006]** In an example, the method comprises:

b) sending the set of parameters to a designer;
c) calculating by the designer at least one new design for the at least one internal part or the insulating body; and
d) generating the at least one instruction order, the generation comprising utilisation of the at least one new design.

**[0007]** In an example, step g) comprises testing the at least one internal part or the insulating body.

**[0008]** In an example, the method comprises:

h) optimising the set of parameters, the optimisation comprising utilisation of the quality information.

**[0009]** In an example, step f) is carried out at a substation producer site, and wherein the method comprises delivering the at least one part or insulating body to the customer's site.

**[0010]** In an example, step f) is carried out at the customer's site.

**[0011]** In an example, step f) is carried out at a laboratory/testing site, and wherein the method comprises delivering the at least one part or the insulating body to the customer's site.

**[0012]** In an example, steps f) and g) are carried out simultaneously.

**[0013]** In an example, step g) is carried out after step f).

**[0014]** In an example, step g) is carried out manually.

**[0015]** In an example, step g) is carried out automatically by a different system to that used in step f).

**[0016]** In an example, in step e) the sending comprises using a secured digital protocol, and/or in step g) the providing comprises sending the quality information to the customer's site using a secured digital protocol.

**[0017]** In a second aspect, there is provided a low, medium or high voltage transformer, wherein at least one internal part or insulating body of the transformer is manufactured according to the method of the first aspect.

**[0018]** In an example, the transformer is a current transformer.

**[0019]** In an example, the transformer is a voltage transformer.

**[0020]** In an example, the transformer is configured to be a power transformer or an instrument transformer.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0021]** Exemplary embodiments will be described in the following with reference to the following drawings:

Fig. 1 shows a typical design of a current transformer;
Fig. 2 shows a typical design of a voltage transformer;
Fig. 3 shows a cross section of a voltage transformer core and winding; and
Fig. 4 shows an example of a transformer part delivery and production workflow.

## DETAILED DESCRIPTION OF EMBODIMENTS

**[0022]** Fig. 1 shows a typical MV Current transformer (CT) found today. The transformer of Fig. 1 has several main parts, being produced independently and then assembled together. An Insulating body 1 is made of some insulation material, typically thermoset. A primary terminal 2 needs to fulfill dimensions given by some standards or customer requirements. Primary terminals 2 are internally connected to the primary conductor 3. The connection of the primary conductor 3 to the second primary terminal 2 is usually done after the primary conductor is placed through the secondary winding 4, which may be quite difficult as the secondary winding 4 can be quite bulky. If the connection is done before the final assembly, the inner hole in the secondary winding 4 must be big enough to allow the primary terminal 2 to go through. This leads to the requirement for quite a big dimension of the secondary winding and a resulting CT size will be also quite large. In case of a multiturn primary design of CT, the primary conductor needs to be placed several times within the secondary winding, creating non effective utilization of space within the inner hole of the secondary winding.

Fig. 2 shows a typical MV voltage transformer (VT). The transformer has several main parts, being produced independently and then assembled together. An insulating body 10 is made of some insulation material, typically thermoset. A primary winding 12 is positioned over the secondary winding 13 and the whole assembly is moved over the ferromagnetic core 14. A typical ferromagnetic core cross section with applied winding is shown in Fig. 3. As shown, there are several "steps" in the core, due to the way it is produced, and where the space between the core and the winding is not completely utilized. Rather, this is dictated by core production technology and assembly procedures, which need to consider such space margins.

**[0023]** The above issues are addressed by the method of producing parts of a medium voltage transformer, as described below, which applies to low, medium and high voltage transformers.

**[0024]** Fig. 4 shows an example of a MV part delivery and production workflow. This relates to a method of producing parts of a transformer, for example a CT or VT design, and in addition to enabling parts to be produced and assembled in a new and different way, space savings for the CT and VT are provided. This is described with respect to a medium voltage transformer but also applies to low and high voltage transformers. The method comprises:

a) providing a set of parameters for at least one internal part or insulating body of a MV transformer to be located at a customer's site;
e) sending at least one instruction order to one or more additive manufacturing printers, wherein the at least one instruction order is based on the set of parameters;
f) producing by the one or more additive manufacturing printers the at least one internal part or the insulating body, the production comprising utilisation of the set at least one instruction order; and
g) providing quality information on the manufactured at least one internal part or the insulating body.

**[0025]** According to an example, the method comprises:

b) sending the set of parameters to a designer;
c) calculating by the designer at least one new design for the at least one internal part or the insulating body; and
d) generating the at least one instruction order, the generation comprising utilisation of the at least one new design.

**[0026]** According to an example, step g) comprises testing the at least one internal part or the insulating body.

**[0027]** According to an example, the method comprises:

h) optimising the set of parameters, the optimisation comprising utilisation of the quality information.

**[0028]** According to an example, step f) is carried out at a substation producer site, and wherein the method comprises delivering the at least one part or insulating body to the customer's site.

**[0029]** According to an example, step f) is carried out at the customer's site.

**[0030]** According to an example, step f) is carried out at a laboratory/testing site, and wherein the method comprises delivering the at least one part or the insulating body to the customer's site.

**[0031]** According to an example, steps f) and g) are carried out simultaneously.

**[0032]** According to an example, step g) is carried out after step f).

**[0033]** According to an example, step g) is carried out manually.

**[0034]** According to an example, step g) is carried out automatically by a different system to that used in step f).

**[0035]** According to an example, in step e) the sending comprises using a secured digital protocol, and/or in step g) the providing comprises sending the quality information to the customer's site using a secured digital protocol.

**[0036]** Thus, the above described method results in a MV transformer, where at least one internal part or insulating body of the MV transformer is manufactured according to the described method.

**[0037]** According to an example, the transformer is a current transformer.

**[0038]** According to an example, the transformer is a voltage transformer.

**[0039]** According to an example, the transformer is configured to be a power transformer or an instrument transformer.

**[0040]** The current size and design of an instrument or power transformer is limited by the way it is produced and corresponds to the state of the art of its component's manufacturing as well. Thus, the described method applies a new production method that of additive manufacturing technology (e.g. 3D printing) to make the design and production of parts of a MV transformer much more effective, i.e. smaller size, improved quality etc. An associated significant advantage and improvement is changing of the business model that will create totally new and advantageous business opportunities for customers by changing a traditional supply chain network and skipping a number of existing manufacturing steps. The described method utilizes for example real-time web-based printing possibilities followed by proper quality check in-situ, e.g. in the case of missing spare parts for existing installations. Web-based real-time feedback in-situ directly after printing of the printing data is conducted in order to realize an immediate quality check by the data owner (the customer or component designer) of the printed product. This is important in the sense of digital, industry 4.0 and 6 Sigma proces.

Thus, additive manufacturing technology that has emerged from being a new technology is used to produce various parts for MV transformers.

**[0041]** Therefore, all or at least some internal parts and insulating body of a MV transformer, such as a CT or VT, can be produced using the described method that utilizes additive manufacturing technology (3D printing). Thus for example, for a VT produced in this manner the core of the VT can be produced by additive manufacturing technology with a round cross-section, as opposed to existing stepped cores), and the area between the core and the winding can be fully utilized. This leads to increased power that can be transferred through the VT, or to a smaller size of VT whilst maintaining existing parameters. Furthermore, winding and terminals can also be produced by additive manufacturing technology as well as the base plate and whole insulating body.

**[0042]** If a 3D printer is available at a manufacturer of the transformer parts, they can print the necessary parts needed for transformer assembly and thereby avoid waiting for delivery of necessary parts from suppliers. This will significantly decrease the delivery time of a transformer, especially in the case of critical components. As a large number of different materials are available for 3D printing, all the internal parts as well as the insulating body can be produced by additive manufacturing technology (3D printing), enabling the total throughput time of a product to be shortened. The method can be extended even to the final customer/user, so he can himself print the parts of the MV transformer at the final place or close to the testing facility. Thus if a customer can test the unit in his or nearby facility, a printer or set of printers for additive manufacturing steps can be placed at the customer premises and then the printing software and design can be managed as required, for example by a supplier. This dramatically decreases transport time and costs and can reflect last minute customer modifications. Whole production is then fully autonomous, without any human interaction, so the quality of products improves and at the same time quality/design for each printed unit improves.

The method can be further used in the manufacture or production of all kind of transformers, covering all voltage levels and environmental conditions. Other devices being part of switchgears, like busbars, support insulators etc. could also be produced using the same approach as well.

**[0043]** The method is shown simply in Fig. 4. A customer sends transformer parameters to the configurator. In case this is a totally new configuration, parameters are sent to a designer, who calculates the new design. The new or existing design is sent to the additive manufacturing printer (3D printer) or set of printers, that print one or some parts of the transformer or even the whole transformer. In order to make a product check, quality inspection needs to be done, providing feedback to the designer or configurator if the printed part should be discarded and a new piece printed or if it can be sent to routine tests and warranty then guaranteed. The product or part then needs to be routine tested in order to make sure the accuracy parameters are fulfilled and there are no dielectric issues which can lead to failures or safety issues. In an advanced approach, the whole design process can be linked with dedicated design optimisation software enabling algorithms with function goals resulting in a number of additional product benefits as minimised electrical fields, reduced weight, etc.

**[0044]** The quality inspection step accommodates several sensing and checking means, in order to qualify the quality of the printout / printed part. This can be done either simultaneously during printing or after the printing step is finalized.

**[0045]** The method described here reduces the need for transformer factories/production, since the printing can be done at customer premises to decrease delivery time and transportation costs as well as necessary shutdown time of a substation (in case of service activities). The method can be used with and by sub-suppliers, i.e. a sub-supplier can send a 3D model to the factory producing the transformer and the relevant part or sub-part is printed directly in that factory, providing a introduction of 3D printed parts into production of an transformer. Thus, some parts can be 3D printed, and some manufactured in a conventional way. However, the opportunity exists to manufacture all components using the described method, and thus full transformer production can be done by 3D printing in the manufacturing factory first, with later introduction to the final customer/user. Appropriate data share between the customer, designer and printer then ensures a safe, secure and reliable data transfer for the production method.

**[0046]** The described method using additive manufacturing can be applied to other power parts used in electric power industry, e.g. busbars, post insulators, bushings, poles, switchgears, etc. It can be used for supply of their internal parts or for supply of the whole product to the final customer.

## Claims

1. A method of producing parts of a low, medium or high voltage transformer, the method comprising:

   a) providing a set of parameters for at least one internal part or insulating body of a transformer to be located at a customer's site;
   e) sending at least one instruction order to one or more additive manufacturing printers, wherein the at least one instruction order is based on the set of parameters;
   f) producing by the one or more additive manufacturing printers the at least one internal part or the insulating body, the production comprising utilisation of the set at least one instruction order; and
   g) providing quality information on the manufactured at least one internal part or the insulating body.

2. Method according to claim 1, the method comprising:

   b) sending the set of parameters to a designer;
   c) calculating by the designer at least one new design for the at least one internal part or the insulating body; and
   d) generating the at least one instruction order, the generation comprising utilisation of the at least one new design.

3. Method according to any of claims 1-2, wherein step g) comprises testing the at least one internal part or the insulating body.

4. Method according to any of claims 1-3, the method comprising:

   h) optimising the set of parameters, the optimisation comprising utilisation of the quality information.

5. Method according to any of claims 1-4, wherein step f) is carried out at a substation producer site, and wherein the method comprises delivering the at least one part or insulating body to the customer's site.

6. Method according to any of claims 1-4, wherein step f) is carried out at the customer's site.

7. Method according to any of claims 1-4, wherein step f) is carried out at a laboratory/testing site, and wherein the method comprises delivering the at least one part or the insulating body to the customer's site.

8. Method according to any of claims 1-7, wherein steps f) and g) are carried out simultaneously.

9. Method according to any of claims 1-8, wherein step g) is carried out after step f).

10. Method according to any of claims 1-9, wherein step g) is carried out manually.

11. Method according to any of claims 1-9, wherein step g) is carried out automatically by a different system to that used in step f).

12. Method according to any of claims 1-11, wherein in step e) the sending comprises using a secured digital protocol, and/or in step g) the providing comprises sending the quality information to the customer's site using a secured digital protocol.

13. A low, medium or high voltage transformer, wherein at least one internal part or insulating body of the transformer is manufactured according to the method of any of claims 1-12.

14. Transformer according to claim 13, wherein the transformer is a current transformer.

15. Transformer according to claim 13, wherein the

transformer is a voltage transformer.

**16.** Transformer according to claim 13, wherein the transformer is a power transformer.

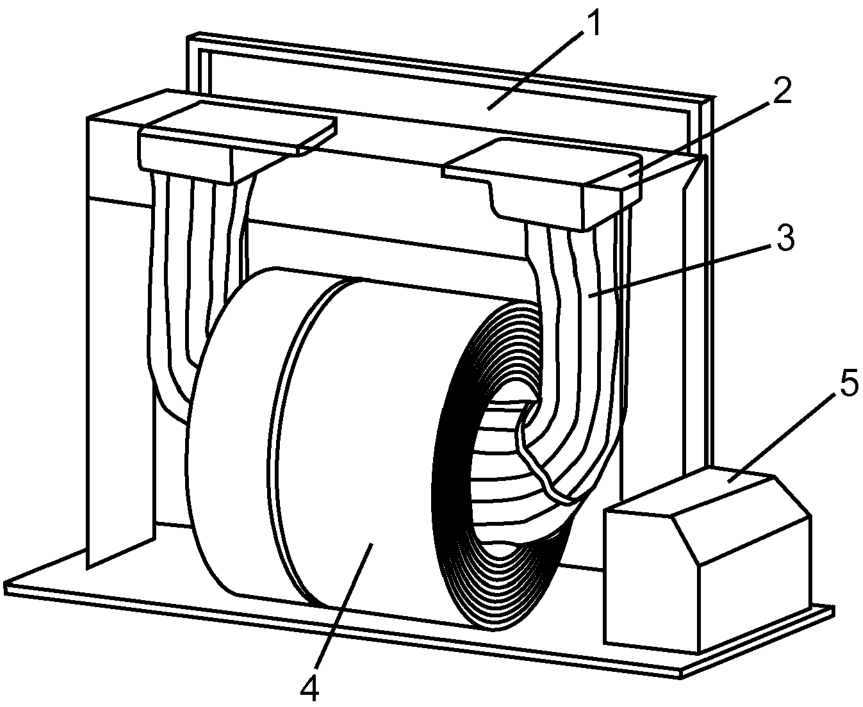


Fig.1

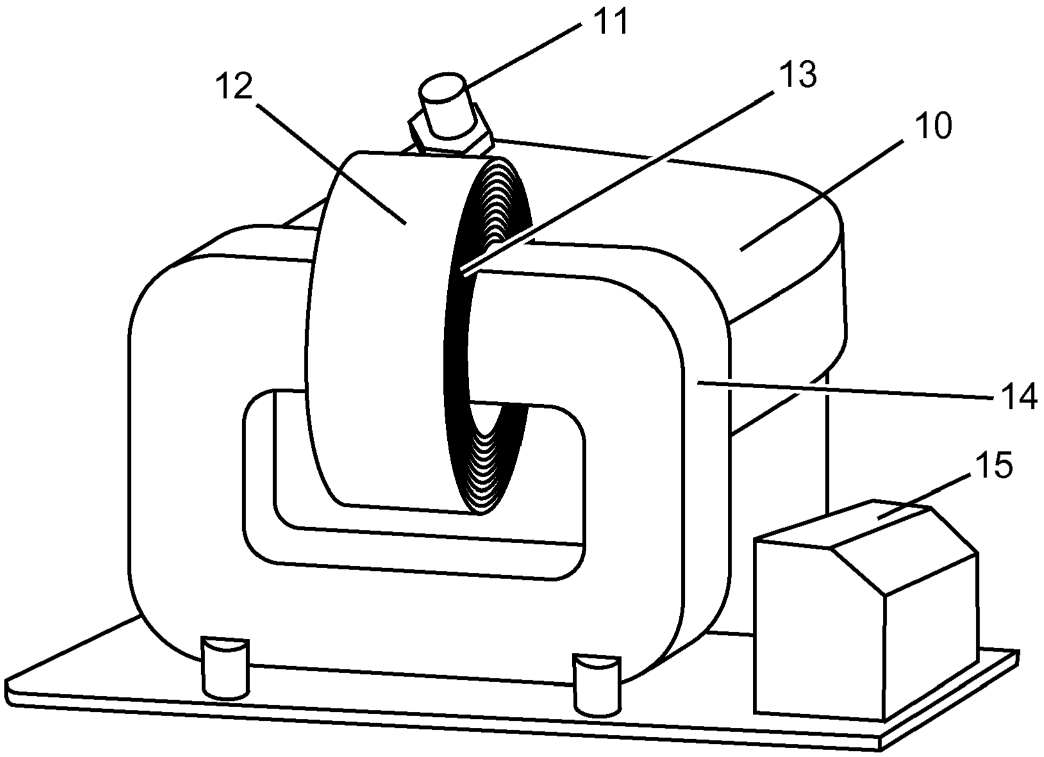


Fig. 2

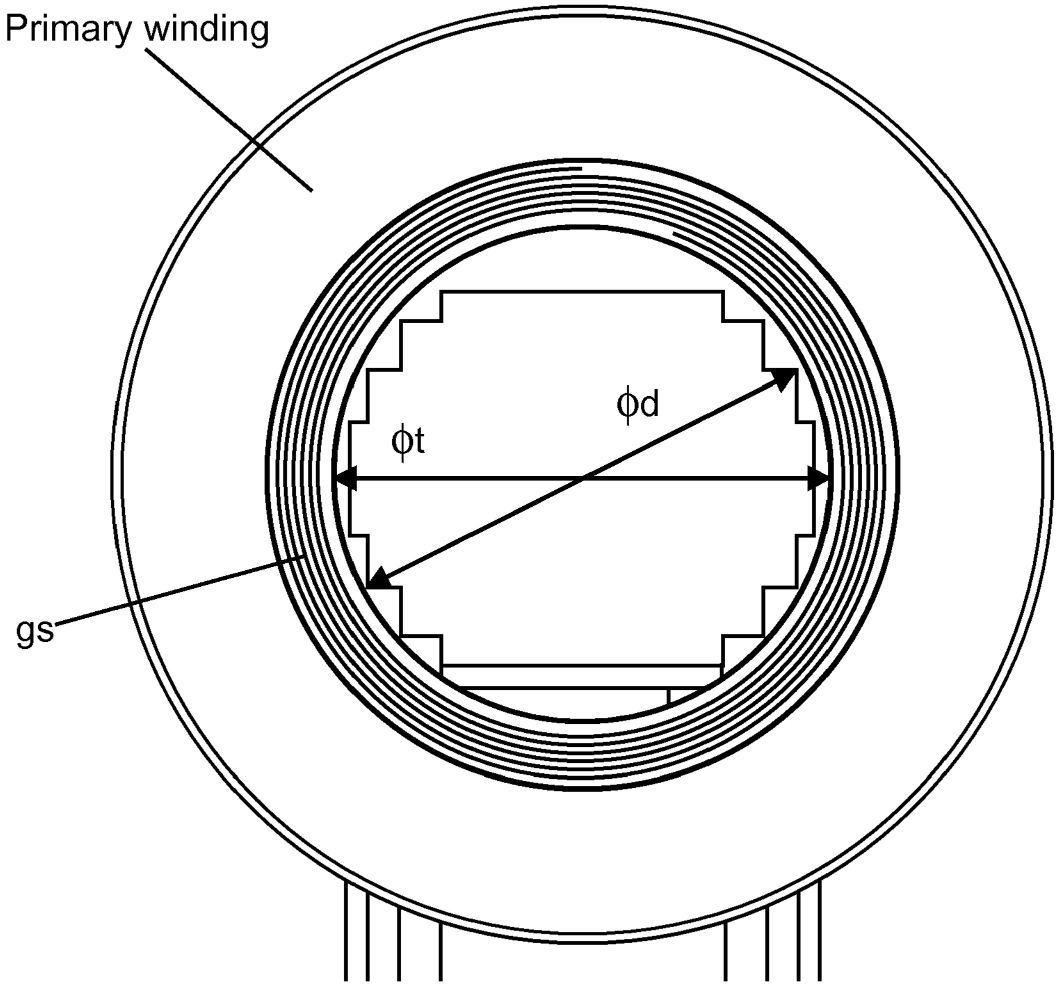


Fig. 3

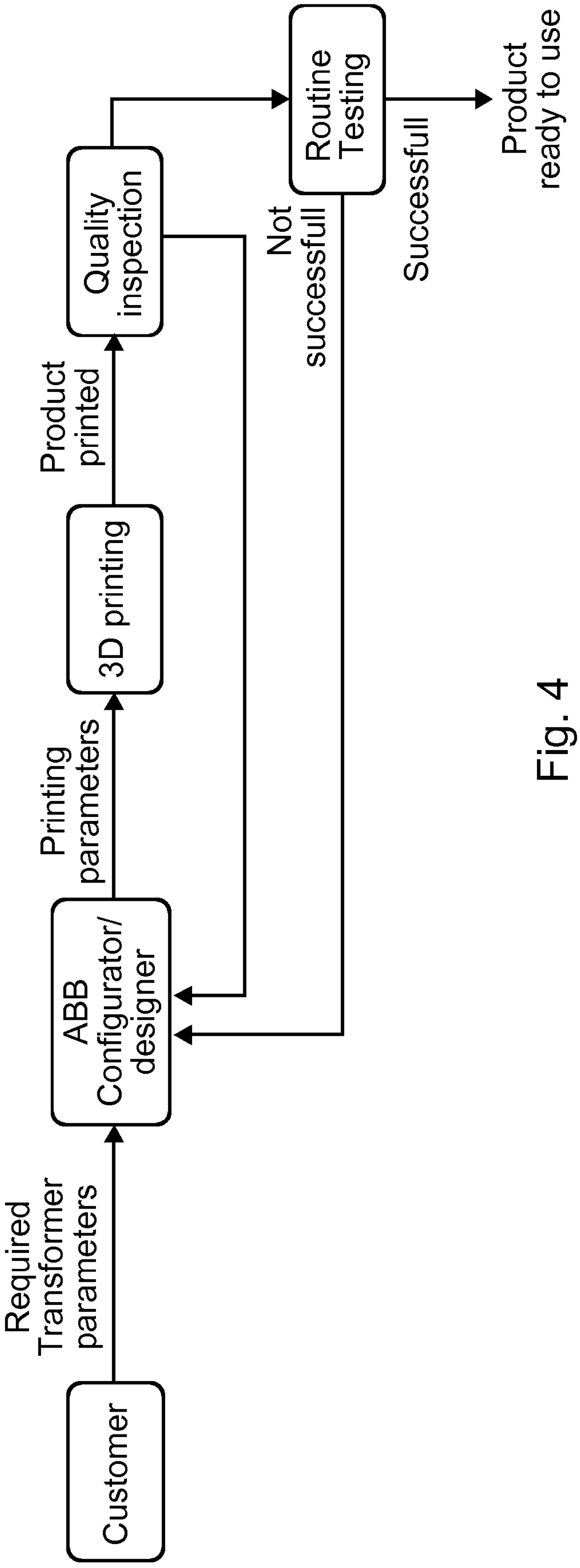
Customer
Required Transformer parameters
ABB Configurator/ designer
Printing parameters
3D printing
Product printed
Quality inspection
Routine Testing
Not successfull
Successfull
Product ready to use

Fig. 4

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# EUROPEAN SEARCH REPORT

Application Number
EP 18 21 4677

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The present search report has been drawn up for all claims

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| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 17 June 2019 | Winkelman, André |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 21 4677

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