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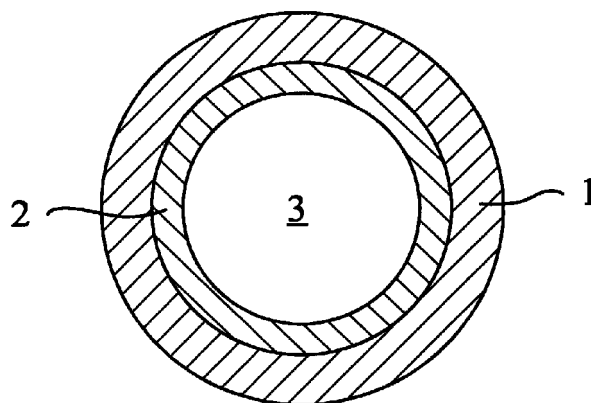
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(54) **Liquid cooled conductor**

(57) The invention relates to a liquid-cooled conductor, comprising a hollow, electrically conductive part (1). An insulating part (2) comprising at least one coolant flow channel (3) is fitted inside the conducting part (1) and is essentially shaped to the inner surface of the conducting part (1) and forms an electrical insulation between the conducting part (1) and the coolant arranged to flow in the flow channel (3).



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Description

[0001] The present invention relates to a liquid cooled conductor according to the preamble of claim 1 and a method for using liquid to cool a conductor, according to the preamble of claim 6.

[0002] So much heat may be lost through voltage losses in the windings and magnetic material of an inductor or transformer that cooling of the inductor or transformer is essential to prevent overheating. One common cooling method is to manufacture the conductor used in the windings from a hollow material, such as copper piping, inside which the liquid used for cooling flows, transferring the waste heat away from where it arises. Water is usually used as the coolant.

[0003] In the solution described above, the water used as the coolant is in direct contact with the charged winding material, so that the impure water electrolyses and begins to conduct electricity. In this case, other electrically conductive components in the cooling circuit, such as pipes, pumps, and heat exchangers, which are in contact with the cooling water, also become charged. The electrical conductivity of the cooling water is also detrimental in applications, in which the winding is divided into several parts with different potentials, which differences in potential prevent the same cooling water from being used throughout.

[0004] To reduce the electrical conductivity, impurities and ions that increase conductivity must be removed from the cooling water. The quality of the cooling water must also be monitored during operation, and, if the electrical conductivity increases, the water may have to be purified and given ion-exchange treatment. The measures and equipment required to reduce the electrical conductivity of the cooling water add considerably to the treatment costs of the cooling water.

[0005] The invention is intended to eliminate the defects of the state of the art disclosed above and for this purpose create an entirely new type of liquid cooled conductor.

[0006] The invention is based on placing an insulating pipe or similar made from a non-conducting material, inside which the coolant flows, inside the hollow conductor used in the winding. The insulating pipe prevents the coolant from coming into electrical contact with the charged conductor. The pipe is pressed tightly onto the inner surface of the conductor, so that the thermal resistance caused between the conductor and the coolant is quite small and thermal transmission is scarcely weakened.

[0007] More specifically, the conductor according to the invention is characterized by what is stated in the characterizing section of claim 1.

[0008] Furthermore, the cooling method according to the invention is characterized by what is stated in the characterizing section of claim 6.

[0009] The invention offers significant benefits.

[0010] By means of the solution according to the

invention, coolant can be insulated from an electrically charged conductor, when the coolant need not be as pure as in non-insulated embodiments, considerably reducing the treatment costs of the coolant. Even normal tap water can be used as the coolant. The number of possible alternative coolants also increases. The invention is also a suitable in solutions, in which the windings are divided into several separate parts, with differing potentials. Because the coolant is electrically insulated from the conductor in the winding, the same coolant can be used in all the parts of the winding, despite their different potentials. The charge is no longer transferred to any other parts of the cooling circuit by the coolant. Electro-chemical corrosion in the conductor and elsewhere in the cooling circuit also decreases. The solution according to the invention can also simplify the cooling circuit, as there is no need to use equipment to purify the coolant and measure its electrical conductivity. A conductor according to the invention is also simple and economical to manufacture.

[0011] In the following, the invention is described in more detail with reference to the annexed drawing, showing a cross-section of one conductor according to the invention.

[0012] The conductor according to the drawing includes a conducting part 1, along which the electrical current travels. Insulating part 2, with a coolant flow channel 3 inside it, is set against the inner surface of conducting part 1. Insulating part 2 may be, for example, a thin-walled pipe, and is intended to create electrical insulation between conducting part 1 and the coolant. Insulating part 2 may be manufactured from, for example, plastic, such as polyethylene, or some other suitable material, which does not conduct electricity. The material of conducting part 1 may be, for example, copper piping. In this case, the conductor can be manufactured by, for example, pushing insulating part 2 into conducting part 1, prior to the final stage of drawing conducting part 1. In the final drawing stage, copper conducting part 1 narrows so much, that it grips insulating part 2 tightly. Thus, the boundary surface between conducting part 1 and insulating part 2 is unbroken, so that the boundary surface's thermal resistance, that hampers heat transfer, is small. Increasing the pressure of the coolant flowing in flow channel 3 of insulating part 2, will press insulating part 2 more tightly against conducting part 1, further reducing the thermal resistance of the boundary surface between them. Insulating part 2 is extended so far beyond the ends of conducting part 1, that the rest of the cooling circuit can be connected to insulating part 2, without touching conducting part 1. If necessary, the sections of insulating part 2 protruding from conducting part 1 can be reinforced to increase their resistance to pressure.

[0013] The conductor according to the invention is used primarily in low-voltage applications, with a maximum voltage of 1000 V. In this case, a sufficient thickness for insulating part 2 is about 0.5 mm. Insulating

part 2 can also be thicker, whereupon the temperature gradient over it will be correspondingly greater. In the dimensioning example examined next, conducting part 1 is manufactured from copper piping with an outer diameter of 10 mm and a wall thickness of 1 mm, giving it a cross-sectional area of about 28 mm². Insulating part 2 is manufactured from plastic piping, with a wall thickness of 0.5 mm and a specific thermal conductivity of 0.25 W/m*K. The current flowing through conducting part 1 is 500 A_{rms}, so that the total heat loss in conducting part 1 is about 155 W/m. Thus, the heat flux through insulating part 2 will be 7 kW/m². If the total length of the conducting part is 6.8 m, the total heat loss will be 1054 W. If the cooling water heats up by 10°C as it flows through the conductor, a cooling water flow of 0.025 dm³/s will be needed for the waste heat created to be transferred away from the conductor. The flow velocity of the water in flow channel 3 of insulating part 2 is about 0.65 m/s, so that there is little risk of erosive cavitation arising in insulating part 2.

[0014] A conductor according to the invention can also be used in embodiments other than the windings of transformers and inductors. Conducting part 1 can also be manufactured from electrically conductive materials other than copper, for example, from aluminium. Points of discontinuity, such as folds or grooves, which increase the turbulence in the coolant, can also be made in the surface of coolant flow channel 3 of insulating part 2. Several, for example 2 - 4, coolant flow channels 3 can also be placed in insulating part 2. In addition, the cross-section of flow channel 3 can, if necessary, be given a shape other than a circle, such as an oval or a polygon.

Claims

1. A liquid cooled conductor, comprising a hollow, electrically conductive conducting part (1), **characterized** in that inside the conducting part (1) there is, fitted to its entire length, an insulating part (2), comprising at least one coolant flow channel (3) and essentially shaped to the inner surface of the conducting part (1), and forming an electrical insulation between the conducting part (1) and the coolant arranged to flow in the flow channel (3).
2. A conductor according to Claim 1, **characterized** in that the insulating part (2) is longer than the conducting part (1).
3. A conductor according to Claim 1, **characterized** in that the conducting part (1) is of copper.
4. A conductor according to Claim 1, **characterized** in that the insulating part (2) is of plastic.
5. A conductor according to Claim 1, **characterized** in that the surface of the flow channel (3) has points of

discontinuity, which increase the turbulence in the flow of the coolant.

6. A method for cooling a conductor using liquid, in which method
 - coolant is fed into the conductor,
 - the coolant is circulated inside the conductor, and
 - the coolant is led out of the conductor,**characterized** in that an electrically insulating part (2), comprising at least one coolant flow channel (3), fitted to the entire length of the conducting part (1) and essentially shaped to the inner surface of the conducting part (1), is formed between the conducting part (1) and the coolant flowing in the conductor.
7. A method according to Claim 6, **characterized** in that the coolant flowing in the flow channel (3) of the insulating part (2) is pressurized to press the insulating part (2) more tightly against the inner surface of the conducting part (1).

