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An Automatic Load Sharing of Transformer using Phase Locked Loop Synchronization

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***Abstract*: Transformers are used as power source in government sectors as well as in private sectors. Each transformer has certain load limit, if it exceeds the limit than the condition is called overload condition which may cause overheating and damage to the transformer windings. In order to prevent this condition, two transformers are paralleled and they have to satisfy certain conditions. This includes same voltage ratio, same delta factor and uniform per unit impedance. The delta factors of transformers may vary in higher ratings and it also causes per unit impedance to vary. This can be avoided using Phase Locked Loop (PLL) synchronization technique. In PLL, the delta factors are synchronized by locking common phase and frequency between transformers. It contains oscillator, low pass filter, amplifier unit. The oscillator is used to produce reference delta factor. The low pass filter is used to filter the large frequency and the amplifier is used to boost the low frequency into required frequency. The required delta factor is obtained and supply is given to the load. The ATmega32 microcontroller unit is used to monitor the load level of transformer. The reference load current value is fired in the microcontroller unit. This unit periodically checks the load current value with reference value. The load depends on current value and so the reference is load current value. When the load current value exceeds the reference value due to overload condition, the microcontroller sends control signal to the relay. This relay closes and pass signal to turn on second transformer and shares the excess load with second transformer. When there is no overloading, the second transformer is turned off by the microcontroller unit. This can be controlled by using microcontroller unit and PLL synchronization unit. Thus, un-interrupted power supply is given even though in overload condition**

***Keywords*: Transformer, Overloading, Phase Locked Loop Synchronization, ATmega32 Microcontroller unit, Uninterrupted power supply.**

1. Introduction

A typical grid consists of a three section grid to that all generating stations feeds energy and from that all substation faucets energy. Electrical energy from the sub stations is then transmitted to distribution transformers and from this, the energy is fed to various loads. The components of power system are generating stations, Power transformers, Transmission lines, Substations, Distribution transformers and load. The power is generated in generating power plant and it is transferred to consumers through various transmissions and distribution processes which involves step up and step down of voltage by transformers. The power system includes three Power travels from the power plant to consumer through the system called power distribution system. For power to be very useful it comes off by transmission grid and it is stepped down to the distribution grid. The conversion from transmission to distribution occurs in power substation. The distribution transformers are used to step down the high voltages to the required level. Distribution transformers are one of the most important equipment in power systems where is also known as service transformer. It provides the ultimate voltage transformation within the power distribution system. This transformer's core is constructed using lamination of sheet steel stacked and either glued together with resin or banded together with steel straps to reduce the eddy current losses. There are two winding and they are primary winding in which the input supply is given and secondary winding from which the output voltage is taken without altering its frequency. The reliable operation of power system depends on effective functioning of distribution transformer. The transformers may be damaged due to conditions like overloading and overheating. This can be prevented by incorporating parallel operation and load sharing of transformers. Parallel operation is economical to install number of smaller rated transformers in parallel than installing bigger rated electric transformers. The transformers are said to be in parallel operation when their primary windings are connected to a common supply, and the secondary windings are connected to the common load.

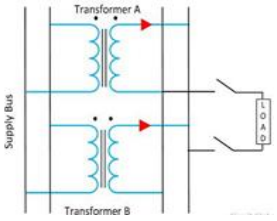

Fig. 1. Parallel operation of transformer

When the load is increased, the load is shared between two transformers which protect the transformers from the damage. In order to share the load, they should satisfy certain conditions. If it is unsatisfied, we need to synchronize them. In alternating current electric power system, synchronization is the process of matching the speed and frequency of a generator or other source

to a running network. A transformer parallel operation is efficient unless the phase angle difference and per unit impedance is same. This can be achieved by synchronization process where the phase angles and per unit impedance value of two transformers are matched through various techniques. A PLL is used as synchronization technique. A PLL is an electronic circuit with a voltage or current driven oscillator that is constantly adjusted to match in phase with the frequency of an input signal. During overload condition, two transformers are paralleled.

While paralleling two higher rating transformers, there may be frequency mismatch and the delta factors also may vary which can be avoided using PLL. The basic idea of this technique is to evaluate the phase angle difference between input and output signal. Thus the phase angle of transformers is synchronized and given to load, and it helps us to prevent short circuit damages.

2. Existing system

In the Existing system, only one transformer is operated to feed the loads. A standby transformer is connected in parallel through a circuit breaker and relay. The current transformer continuously measures the load current and feeds it to the microcontroller ADC pins. The reference value or the maximum load limit is entered by the user and priority level of the load is also set by the user or concerned authority. As the load demand increase during peak hours, a single transformer would not be able feed all the load. During this condition, when the load demand exceeds the reference value, the microcontroller will give a control signal to energize the relay coil. The standby transformer will be connected in parallel and will share the load equally since the transformers are of the same ratings. Thus all the loads are fed efficiently providing un-interrupted power supply. The GSM modem will send a message to the control room about the load sharing and a display will be shown in the LCD display. When the load increases further to a value which is greater than the capacity of the two transformers, priority based load shedding will be implemented. The loads which have the lowest priority will be shut down by opening the respective circuit breakers. This message is also sent to the control room. When the load decreases, and comes to normal working condition, first transformer will be shut down in order to avoid thermal overloading. This is done because the first transformer operates for a longer time interval than standby transformer and its body temperature rises. By providing alternative switching, the transformers can be cooled by natural methods. Each time the GSM will send message about the active transformer thus making load sharing and load shedding efficient. In normal condition, System is healthy system and all the loads are continuously run without any interruption. At the time of temporary fault occur on the line transformer will not share its load with another transformer. At the time of permanent fault, the isolated load will be shared by another transformer and give the reliable power to the consumer.

The distribution transformers are protected from unexpected power failures due to overloading and overheating condition. The above conditions occur when the demand increases with growing population. Temperature of transformers is monitored and the load is shared between two transformers, when it exceeds the rated condition. Power factor is increased with the help of this system and load is shared automatically. The 8051 microcontroller is used to control the transformers on and off process and load current is compared with the reference value according to which control signal produced. There may short circuit of transformer due to varying frequency in high rating.

3. Proposed system

In the proposed system, the two transformers are synchronized using PLL and then the load is shared with the help of microcontroller. The microcontroller unit is used to compare the reference load current value with the actual load current value. When there is overloading condition, single transformer is insufficient to support the demand, and it requires second transformer. During this case, load current value exceeds the reference value and microcontroller produces control signal which is given to relay. The relay turns on the second transformer to share the load. The two transformers can perform parallel operation only if their phase angle difference and per unit impedance values are same. In order to synchronize their difference, PLL is used in this system.

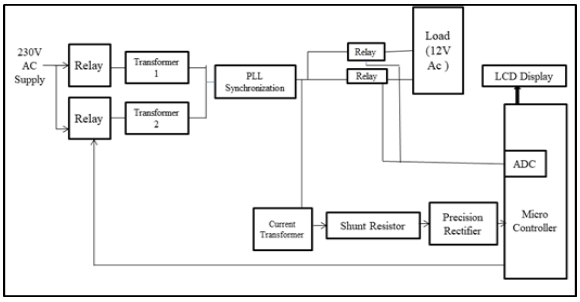

Fig. 2. Automatic Load Sharing of Transformer using Phase Locked Loop Synchronization

A PLL is a circuit that is used to generate synchronized output with respect to the given input. The delta factors of two transformers are synchronized and load sharing operation is carried to protect the transformers. The PLL which is a nonlinear feedback system where the phase of input signal is tracked. The PLL contains a Phase detector (PD), Time-invariant linear loop filter and Voltage-controlled oscillator (VCO).

The output of the phase detector is the input of the VCO and the output of the VCO is connected to one of the input of phase detector. A DC output of the phase detector voltages is input to the low pass filter where it removes the high frequency noise and produce a steady DC level then it is passed to the VCO. The input and output frequencies are compared and adjusted

through the feedback loop until the output is equal to the input.

The PLL is used as a zero crossing comparator where the per unit impedance of two transformers can also be compared and synchronized to the reference value. In three phase transformers, the phase angle between three phases may vary and the vector group may also change which can be synchronized. But in single phase transformer, the phase angle difference between phase and neutral is very low value. Hence, the per unit impedance value is synchronized.

4. Introduction

A. Simulation and hardware results

The automatic load sharing of transformer is simulated with the help of proteus software. The components connected in the simulation are 12V transformers with 1 A and 500 mA, resistive load along with capacitive load. It also includes voltage sensor and current sensor. Relay coils are used as switching device in the circuit. The Arduinos board is connected with the relay coil where the reference load value is compared with the actual load current value. The CRO is used to display the synchronized output waveform.

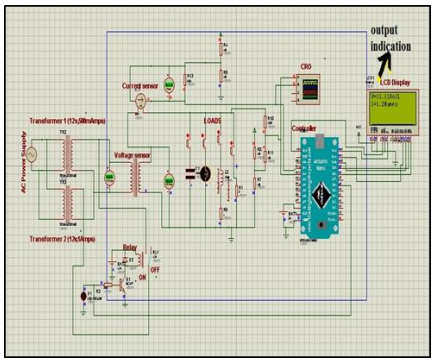

Fig. 3. Simulation Circuit

The LCD display which is connected with the microcontroller unit shows the current value of transformer. This display indicates which transformer is sharing the load and their frequency. The output waveforms of the simulation are shown below which displays the current value of two transformer and how they have been synchronized. The efficiency of load sharing is increased by using rectifier circuit. Initially, there is no overloading condition. So, the first transformer is turned on and the second transformer is in off condition.

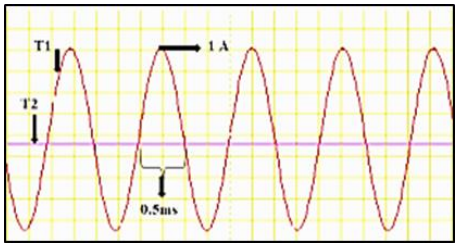

Fig. 4. Before load sharing

When there is overload condition, the second transformer is turned on and it shows the variation in impedance values of two transformers and is shown below.

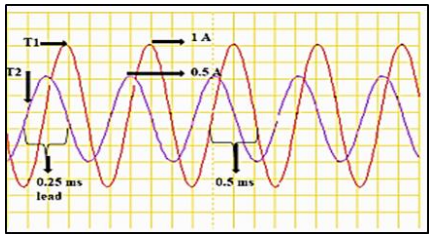

Fig. 5. Before synchronization

The PLL is used to synchronize the difference and the synchronized output is shown in Fig. 6.

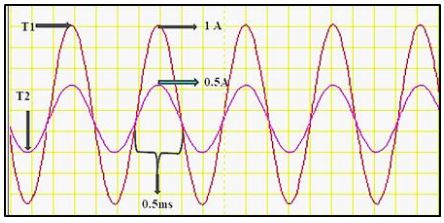

Fig. 6. After synchronization

The hardware of the system includes two transformers which is 12 volts with 1 A and 500mA. Also 5V microcontroller, 12V relay, LCD display, capacitors to filter the noise, comparator, LEDs, voltage regulators of 5V and 12V, voltage divider circuit and current transformer. The hardware kit is shown below.

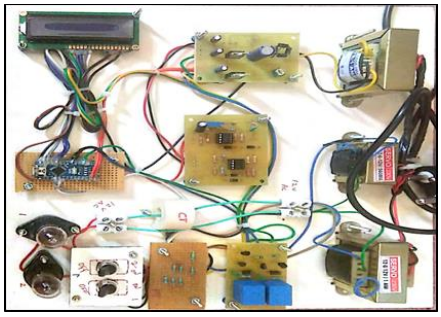

Fig. 7. Hardware

B. Output

Table 1
Status of Transformer

S. No	Transformer (T)	Status of Transformer	
		Before Load Sharing	After Load Sharing
1.	T1	ON	ON
2.	T2	OFF	ON

The second transformer is turned on, only if there is any overload condition. The load current value which is greater than 1.25 A is considered as overload condition.

The efficiency of this system is compared with existing system and it indicates that the efficiency is increased with PLL synchronization, which is shown Fig. 8.

Table 2
PLL Synchronization

T	Before Synchronization						After Synchronization		
	Before Load Sharing			After Load Sharing			X axis (A)	Y axis (ms)	Z (Ω)
	X axis (A)	Y Axis (ms)	Z (Ω)	X axis (A)	Y Axis (ms)	Z (Ω)			
T1	1	0.5	6	1	0.5	6	1	0.5	24
T2	-	-	30	0.5	0.25 lead	30	0.5	0.5	24

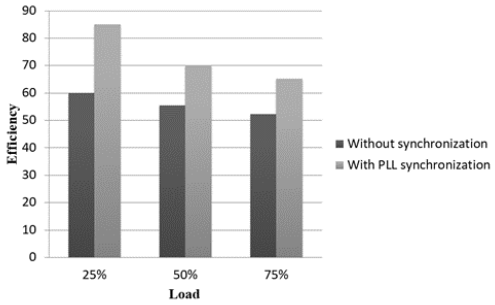

Fig. 8. Efficiency

5. Conclusion

Thus, an automatic load sharing of transformer using PLL synchronization has been successfully designed and executed. When there is overloading condition, the standby transformer is supported with second transformer where it is turned on with the help of microcontroller and relay switches. The impedance and the delta factor of two transformers may vary and this is synchronized with PLL. The load is shared equally where it prevents the overload condition and protects the transformers from damages with increased efficiency.

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