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Compatrative Study of Power Supply of 50 Hz 220v and 60 Hz 110 V

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Abstract—In some country there is a power supply of 50 Hz 220 V and in some country 60 Hz 110 V. There exist some logic and we can say that there is no any logic between them. When we go through the history of this topic then we got that there is no any logic but if we think about it in term of Electrical Theories then we got some absolute logic of these power supply. It holds some advantages and disadvantages and also some losses. We took a look on this matter and observe some parameters which are really interesting and necessary to know about them.

Keywords: -50 Hz 220 V, 60 Hz 110V, Eddy Current Loss, Hysteresis Loss, Efficiency

1. INTRODUCTION

Power supply is an important part of any country. A country development depends upon this power supply. This is one of the factor on which a country depend because without it a country will not be grow up. In some country of the world there is a power supply of 60 Hz 110 V and some country has power supply of 50 Hz 220 V. This power supply holds some advantages and disadvantages, some losses, some lower efficiency or higher efficiency. We observed some of these factors during study.

2. HISTORY OF POWER SUPPLY

First we discussed about 110V 60 Hz Power Supply. In early history Thomas Edition General Electric Company was distributing D.C. supply of 110 V in United Sates. Then Nicola Tesla a great scientist in history build an Three phase electric motor which was operate in 220 V AC. Three Phases means three alternating current supplies in a single device. Then he developed three phase AC supply to distribute and keep 220 V. Then he completed some experiments and observed 60 Hz frequency is more effective and he makes a compromise with voltage and develop device of 60 Hz which operate on 110 V due to safety reasons. The most popular company of the United States Westinghouse Company signed to Nicola Tesla and they started to manufacture devices of 60 Hz and 110 V. But in Europe a most popular company AEG started

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generating 50 Hz frequency for monopoly in Europe but they keep voltage level same as 110 V. Due to this voltages level they observe so many losses and lower efficiency than 60 Hz supply. Due to slower speed the 50 Hz generator is 20 % less efficient than 60 Hz due to 110 V supply. Europe stayed on this power supply till World War II. In 1950 Europe had not much electrical appliances so they think to increase voltage level up to 220 V and stayed continue to his monopoly. Now at this voltage level they observe better efficiency than 60 Hz 110 V power supply. Great Britain also switches to 220 V supply and also change his frequency to 50 Hz. The changes in the Great Britain were not so costly because at the time of World War II they had not much more electrical devices. Now the world is divided in to two power supply one was 50 Hz 220 V and second was 110 V 60 Hz supply. After the time of World War II United States trying to switch 50 Hz 220 V supply from 60 Hz 110 V but they observed that they have so much electrical appliances and costing to switch the supply is much larger so they stayed on same power supply.

Some power supply system in different country is shown in Table 1.

We discussed history of power supply and now we will prove some factors of Power Supply 50 Hz 220 V and 60 Hz 110 V. Some factors like Efficiency, Reliability, Losses, Costing, Advantages, Disadvantages and comparison of both two type of power supply one by one.

3. ANALYSIS OF POWER SUPPLY

We discussed some parameters one by one and shows result.

3.1.EFFICIENCY

Lower frequency gives the lower line reactance which will be prove on this basic formula of reactance.

$$X_L = 2 \times \pi \times f \times L$$

Where f = frequency of the current

L = Inductance of the Transmission Line

Here it proves that frequency is directly proportional to the Reactance of the transmission line if we take other parameters constant for a particular material of transmission line. Higher frequency gives greater reactance so in transmission; the distance will be decrease as per compare to the lower frequencies. So lower frequency can be transmit more distance than higher frequencies.

Table 1: Power supply system in different country

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North America

Canada	120V/60Hz
United States	120V/60Hz

Central America

Anguilla	220V/50Hz
Antigua	220V/50Hz
Bahamas	115V/60Hz
Barbados	115V/60Hz
Belize	110V/60Hz
Bermuda	115V/60Hz
Costa Rica	120V/60Hz
Cuba	120V/60Hz
Dominica	110V/60Hz
Dominican Republic	110V/60Hz
El Salvador	115V/60Hz
Grenada	220V/50Hz
Guadeloupe	220V/50Hz
Guatemala	115V/60Hz
Haiti	110V/60Hz
Honduras	110V/60Hz
Jamaica	110V/50Hz
Martinique	220V/50Hz
Mexico	120V/60Hz
Monteserrat	220V/60Hz
Neth. Antilles	120V/50Hz
Nicaragua	120V/60Hz
Panama	120V/60Hz
Puerto Rico	120V/60Hz
St. Kitts & Nevis	220V/50Hz
St. Lucia	240V/50Hz
St. Vincent	220V/50Hz
Trinidad	120V/60Hz
Virgin Islands	120V/60Hz

South America

Argentina	220V/50Hz
Bolivia	110V/50Hz
Brazil	110-127-220V/60Hz
Chile	220V/50Hz
Colombia	110-120V/60Hz
Ecuador	110-120V/60Hz
French Guiana	220V/50Hz
Guyana	110V/60Hz & 240V/50Hz
Paraguay	220V/50Hz
Peru	220V/60Hz
Surinam	110-127V/60Hz

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Uruguay	220V/50Hz
Venezuela	120V/60Hz

Europe

Gibraltar	240V/50Hz
Malta	240V/50Hz
United Kingdom	240V/50Hz
All Others	220V/50Hz

Africa

Ghana	240V/50Hz
Kenya	240V/50Hz
Liberia	120V/60Hz
Libya	110-115V/50Hz
Morocco	120V/50Hz
Senegal	110V/50Hz
Seychelles	240V/50Hz
Sudan	240V/50Hz
Uganda	240V/50Hz
All Others	220V/50Hz

Asia and the Pacific

Australia	240-250V/50Hz
Fiji Islands	240V/50Hz
Papua New Guinea	240V/50Hz
Solomon Islands	240V/50Hz
Tahiti	127V/60Hz
Brunei	240V/50Hz
China	250V/50Hz
Japan	100-200V/50 or 60Hz
Korea (North)	220V/60Hz
Korea (South)	110-220V/60Hz
Malaysia	240V/50Hz
Philippines	110-220V/60Hz
Sabah	240V/50Hz
Taiwan	110V/60Hz
Vietnam	120V/50Hz
All Others	220V/50Hz

Middle East

Abu Dhabi	240V/50Hz
Canary Islands	127-220V/50Hz
Cyprus	240V/50Hz
Kuwait	240V/50Hz
Lebanon	110-220V/50Hz
Muscat	240V/50Hz
Oman	240V/50Hz

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Qatar	240V/50Hz
Saudi Arabia	127-220V/50 or 60Hz
All Others	220V/50Hz

If talk about transformer and motors then we observe the idea that the efficiency of motor and transformer is less at lower frequencies. But in case of transformer the iron material or core material will be used more at lower frequency. Lower frequency need more core element in the transformer. When Europe applied 50 Hz and 110 V supply then they observed very less efficiency of motor on such a lower voltage but when they change their voltage to 220 V then the efficiency increased and they apply it in whole Europe and so many country changed their system and follow to Europe.

3.2.RELIABILITY

If we talk about reliability then both type of power supply is reliable but 60 Hz 110 V is better than 50 Hz 220 V because it is safe than other. Due to low voltage economically the shock is less effective on human. According to Nicola Tesla 60 Hz frequency is better for earth and it is like natural frequency of earth.

3.3.LOSSES

Losses in the transmission line are more in case of 60 Hz because more frequency means more losses in term of reactance. Due to this losses transmission line distance is less than 50 Hz. Due to higher frequency Eddy Current Loss, Hysteresis Loss, Losses caused by Harmonics, skin effect, etc. observe in case of transformer and motors.

3.4.Eddy Current Loss

The eddy current loss may be expressed as:

$$\int_V \int_{t1}^{t2} \frac{J^2(t)}{\sigma} dt\, dV$$

It can be shown that the average power loss in complex notation is

$$P_e = \int_V \frac{|J|^2}{2\sigma} dV$$

Then after some calculation we got the Power loss due to eddy current which is as follows:

$$Pe(L) = \frac{\pi^2 f^2 B_{max}^2 a^2 \sigma^2}{6}$$

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As per calculation the formula of power loss is as follows. We can see that the frequency is directly proportional if we consider other parameter constant in this equation. Frequency is in square so it gives more eddy current loss in term of transformer if we consider 60 Hz power supply. Here we are taking only one device which is transformer in role.

3.5.Hysteresis Loss

It is the integral which represent the Hysteresis loss

$$\int_{V}^{V1} \int_{B1}^{B2} HdB\ dV$$

When it is taken over a full cycle that is

$$W(per\ cycle) = \int_{V}^{V1} [\oint HdB]\ dV$$

The brackets represent the area of the Hysteresis loop for the element dV under consideration. If the area is expressed as the function of V then we have to integrate over the entire volume to gain the maximum hysteresis loss per cycle. After a long derivation we gain the formula of energy and the Hysteresis loss if f times the energy lost per cycle.

$$P_H = fW = \frac{fbS|\emptyset|^2}{\mu l\delta}\left(\frac{\sinh\frac{a}{\delta} + \sin\frac{a}{\delta}}{\cosh\frac{a}{\delta} - \cos\frac{a}{\delta}}\right)$$

At Power frequencies or when a/ δ<< 1, The Power Loss is

$$P_{h(L)} = \frac{2fBS\emptyset_{max}^2}{\mu la}$$

Now we can see from the formula of Power loss due to Hysteresis loss that frequency is directly proportional to the Power loss. It means the higher frequency has greater loss than lower frequency in case of transformer.

4. COSTING

In previous topic we discussed about the losses of higher frequencies and here we discussed about the coasting of electrical devices due to higher frequencies and lower frequencies. At higher frequency the Eddy current and Hysteresis losses combined to form the total core loss in the transformer. After substitution some equations:

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$$P_{c(H)} = \frac{\pi^{\frac{1}{2}} f^{\frac{3}{2}} \sigma^{\frac{1}{2}} B_{max}^2 a}{\mu^{\frac{1}{2}}} \left(\frac{\pi}{2} + S\right)$$

For a given Bmax and frequencies then the core loss at high frequency is directly proportional to the square root of conductivity and inversely proportional to the square root of permeability. By this consideration if we decrease the core element then we will get lesser core loss in the transformer. So at high frequency the size of transformer is lesser than lower frequencies. It means the costing of transformer is less at higher frequency. Like that other equipment size is really very less at higher frequency than lower frequency. Same as in case of motors, the size of motors is effectively small at higher frequencies. United State didn't change his system due to cost problem. It is not doubt full that Tesla chooses a great frequency in the respect of present day because size and cost both matter in 60 Hz frequency. And today the things gone compact and people like small devices and equipment which is easy to build for 60 Hz frequencies.

5. ADVANTAGES AND DISADVANTAGES OF 50 Hz & 60 Hz

Several advantages and disadvantages hold in both the cases. On this research paper we find some advantages and some disadvantages. First we explain about 50 Hz 220 V supply

Table: 2. Advantage and disadvantage of 50 Hz Supply

	Advantages	Disadvantage
1.	Lower Transmission Reactance.	Not reliable as compared to 60 Hz.
2.	Higher transmission Distance.	Not safe for economical purpose
3.	Lower losses like eddy current losses, Hysteresis Losses, etc.	More core Loss. Due to this large transformer size
4.	Better efficiency.	Costing is more than the 60 Hz due large size.

Now we will discuss about the advantages and disadvantages of 60 Hz supply which we observe in this paper.

Table: 3. Advantages and disadvantages of 60 Hz power supply.

	Advantages	Disadvantage
1	Lower size of Equipment.	Not reliable as compared to 60 Hz.
2	Safe and less effective on human than the 50 Hz 220 V supply	More Losses as compared to lower frequency.
3	Costing of equipment is less	Less Efficient than other power

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	than other power scheme.	scheme.
4	More reliable than the 50 Hz 220 V supply.	Slower speed of motor than the 50 Hz 220 V supply.

6. CONCLUSION

In this research paper we research on two different types of power supply and observe some advantages and disadvantages for that and also discussed about the history of this power supply. Some country of the world follow the United States and some country follow Europe. But after the study that is very clear that United States of America is compromises to their situation at the time of World War II because they were developed and they had much electrical equipment and that's why they could not change their system of power supply due to cost effect. But in this world there are mainly two types of power supply holds with some advantages and disadvantages.

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