# Fractional Frequency Transmission System

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**Abstract**— The fractional frequency transmission system (FFTS) is a recently developing trend in power transmission. In such a system, electrical power is transmitted at a reduced frequency (One third of the rated frequency=50/3 Hz).This approach would be effective in long-distance transmission of electrical power. Transmitting power at a reduced frequency reduces the electrical length of the transmission line (i.e., more amount of power can be transmitted using the same length of the line at reduced frequency than at rated frequency).This paper introduces the experimental installation of FFTS and primary experiment results. The experiment uses cycloconverter as a frequency changer, which is used at the sending end to step the frequency down to 50/3Hz. Similarly, at the receiving end another cycloconverter is used to step-up the frequency back to 50Hz.The FFTS approach proposes new method of increasing the transmission capacity.[1]

**Keywords**— — Fractional frequency Transmission System, Frequency converter, Transmission System, Computer Simulation.

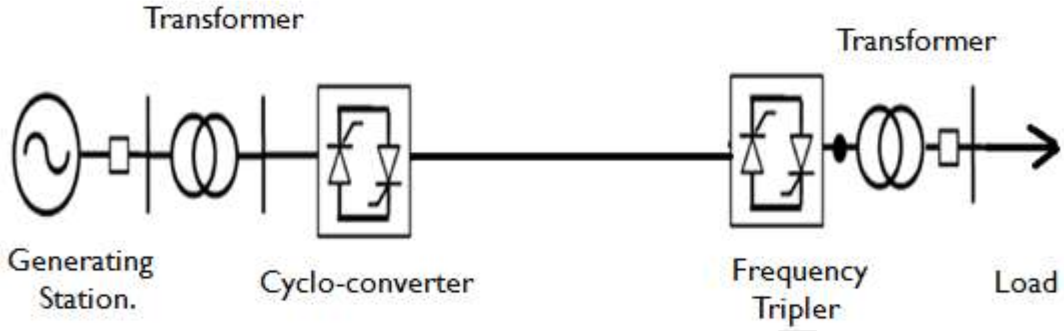
**INTRODUCTION**

In the history of the ac transmission system, increasing distance and capacity mainly depends on raising voltage level of transmission lines. At present, the highest voltage level of the ac power transmission line in operation is 750 kV. To further upgrade, the voltage level encounters difficulties of material and environment issues. The transmission and distribution losses in India currently stand at 27% of the total power being generated. Another method i.e., employed to increase the transmission capacity is the high voltage DC (HVDC) transmission. A HVDC system transmits DC power at a very high voltage. However, at the generation is in AC, it has to employ current converters at transmitting and the receiving ends and these current converters are very expensive. Apart from that, up to now the HVDC practices have been limited to the point-to-point transmission. It is difficult to operate a multi-terminal HVDC system. In 1994, the fractional frequency transmission system (FFTS) was established, which uses lower frequency (50/3 Hz) to reduce the electrical length of the ac transmission line, and thus, its transmission capacity can be increased.[1]

This paper introduces the experimental installation of FFTS and primary experiment results. The experiment uses cycloconverter as a frequency changer, which is used at the sending end to step the frequency down to 50/3Hz. Similarly, at the receiving end another cycloconverter is used to step-up the frequency back to 50Hz.[13] Thus, a new FACTS device is successfully established in this experiment.

## SYSTEM DETAILS

After transformer was invented, it became very easy to transform voltage from one level to another level. Transforming frequency was not as easy as transforming voltage. But now-a-days due to advancement in power electronic & materials it became very easy to transform from one frequency to another frequency. For instance, the lower frequency electricity can be used to transmit larger power for longer distance, and the higher frequency electricity can be used more efficiently to drive the electric tools.




The basic phenomenon of FFTS can be established by using the following two concepts-

1. Three factors limiting the transmission capacity of a line-

Thermal limit, Stability Limit, Voltage drop Limit (Voltage Regulation). For the long-distance ac transmission, the thermal limitation is not a significant impediment. Its load ability mainly depends on the stability limit and voltage drop limit the stability limit of an ac transmission line can be approximately evaluated by-

$$P_{max} = \frac{V^2}{X}$$

Where V is the normal voltage, and X is the reactance of the transmission line. From above equation we see that, transmission capacity is directly proportional to the square of the normal voltage and inversely proportional to the reactance of the transmission line.

The voltage drop ΔV % can be evaluated by-

$$\Delta V\% = \frac{QX}{V^2} \times 100$$

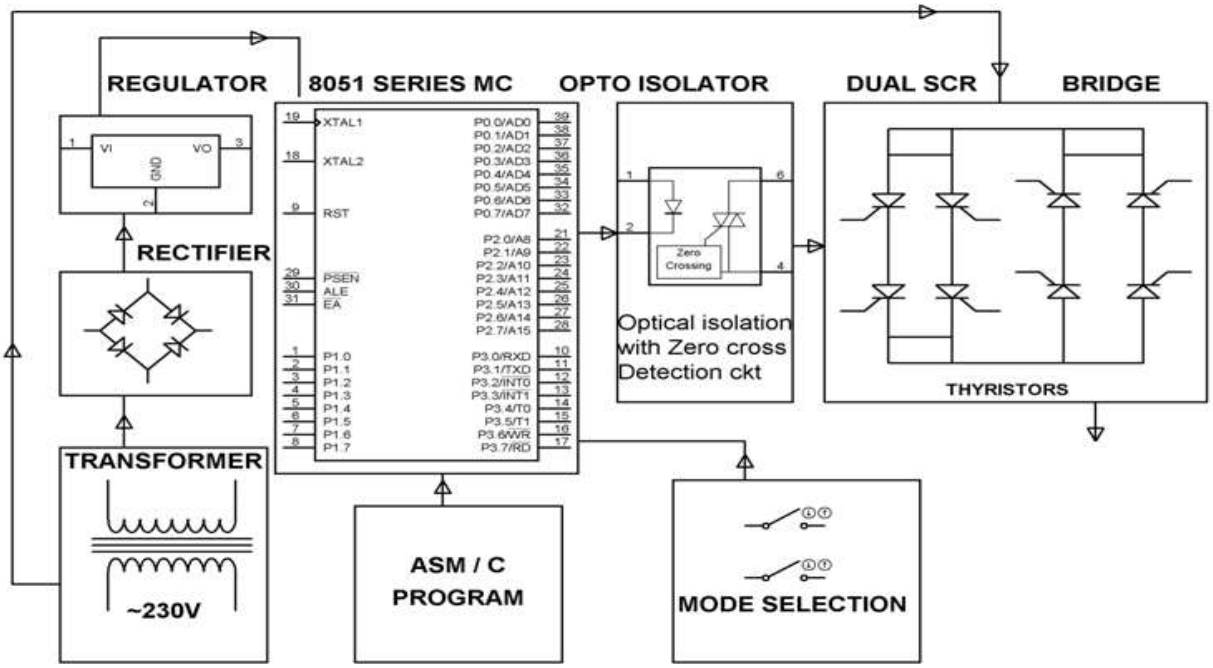
Where Q is the reactive power flow of transmission line. Thus, the voltage drop is inversely proportional to the square of voltage and directly proportional to the reactance of the transmission line. Hence, in order to boost the transmission capability, either the nominal voltage level can be increased or the reactance of the transmission line can reduced. As we know, the reactance is directly proportional to power frequency and is given by-

$$X = 2\pi \, fL$$

Where L is the total inductance of transmission line, calculated by multiplying the inductance per kilometer of the line by length of the line. The inductance per length is calculated based on the type of conductor used. Hence, decreasing the electrical frequency can proportionally increase transmission capability.

Thus FFTS uses reduced frequency to reduce reactance of the transmission system. For instance, when the 50 Hz frequency is reduced by three times, then theoretically, transmission capability increases three times.[1]

## HARDWARE DESIGN




The circuit uses standard power supply comprising of a step-down transformer from 230Vto 12V and a bridge rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor.The filtered dc being unregulated, IC LM7805 is used to get 5V DC constant. The regulated 5V DC is further filtered by a small electrolytic capacitor of 10µF for any noise so generated by the circuit. One LED is connected of this 5V point in series with a current limiting resistor of 330Ω to the ground. i.e., negative voltage to indicate 5V power supply availability. The unregulated 12V point is used for other applications as and when required.

Zero voltage cross detection means the supply voltage waveform that passes through zero voltage for every 10msec of a 20msec cycle. We are using 50Hz ac signal, the total cycle time period is 20msec (T=1/F=1/50=20msec) in which, for every half cycle (i.e. 10ms) we have to get zero signals. Here Op-amp is used as comparator. As we know the principle of a comparator is that when non-inverting terminal is greater than the inverting terminal then the output is logic high (supply voltage). The o/p of this comparator is fed to the inverting terminal of another comparator.Thus we get ZVR (Zero Voltage Reference) detection. This ZVR is then used as input pulses to microcontroller.[9] The output of microcontroller is fed to thyristor circuit .[11]SCR's used in full bridge are in anti-parallel with another set of 4 SCR's as shown in the diagram. Triggering pulses so generated by the MC as per the program written provides input condition to the Opto – isolator that drive the respective SCR. For F/3 the conduction takes place for 30ms in the 1$^{st}$ bridge and next 30ms from the next bridge, such that a total time period of 1 cycle comes to 60ms.

Similarly, at the receiving end another cycloconverter is used to step-up the frequency back to 50Hz.[12]

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## Results and Discussions

MATLAB Simulation Results

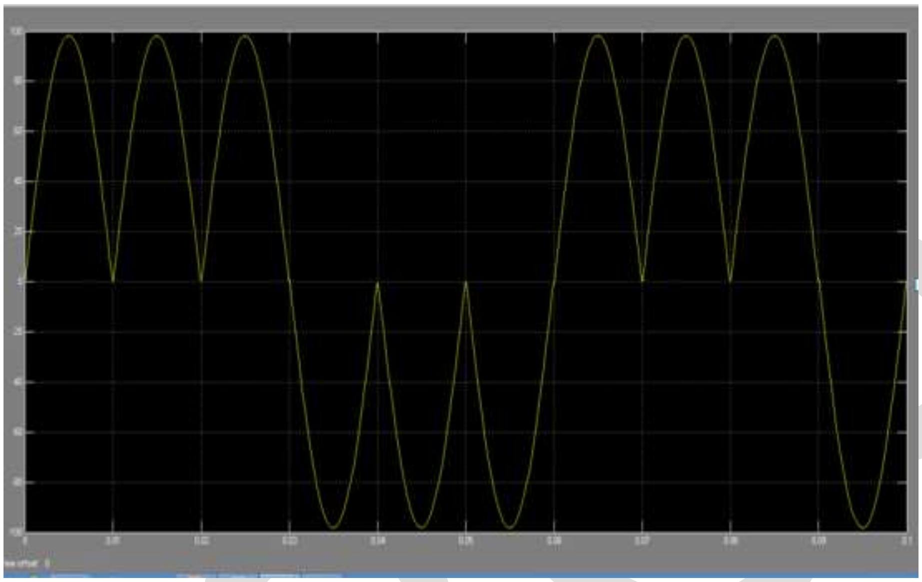

Fig: MATLAB Simulation of down- conversion (50/3Hz)

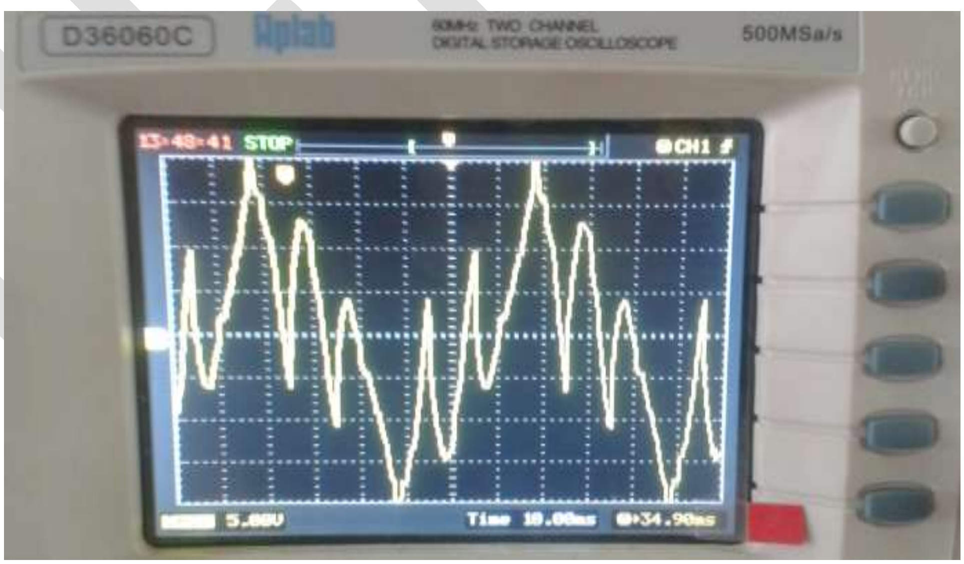


Fig: Output waveform of down-conversion circuit(50/3Hz)

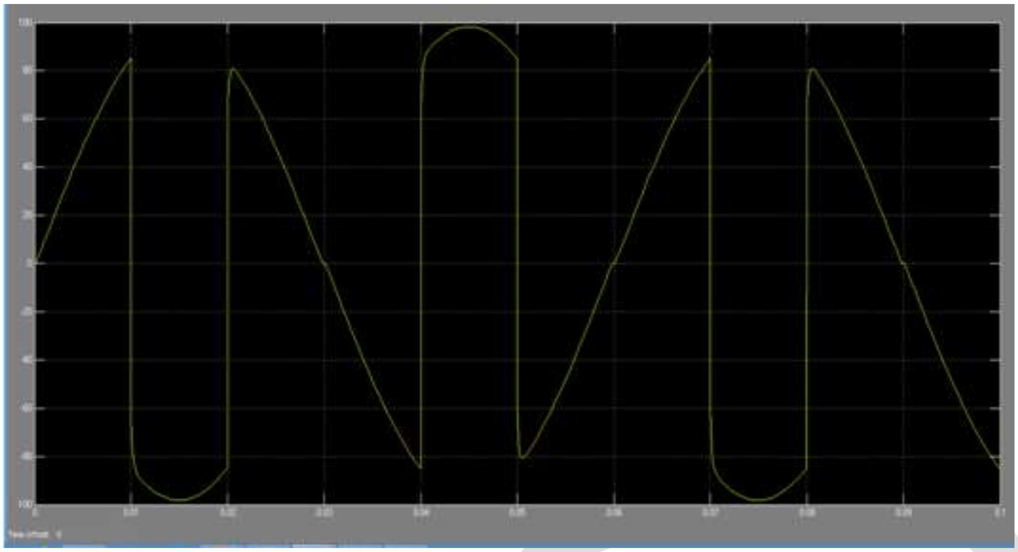

Fig: MATLAB Simulation of up-conversion (50Hz)

The power loss in FFTS is less as compared to the normal transmission system .This can be proved by following formula,

$$P_c = 241 \times 10^{-5} \times \frac{f+25}{\delta}\sqrt{\frac{r}{d}}\,(V_p - V_c)^2 \text{kW/phase/km}$$

Where,

V=Phase voltage (rms Value)

Vd=disruptive critical voltage (rms value)

r=radius of conductor in meter

d=spacing between conductors in meter

f=frequency in Hz

From above equation corona loss is directly proportional to frequency. Hence, as frequency reduces the corona loss also reduces which in turn minimizes the power loss.[7]

**CONCLUSION**

From MATLAB Simulation we found that FFTS is practically feasible. The electrical length of ac transmission line is reduced and hence the transmission capability is increased to several folds. The reduced length of the transmission line leads to the reduction in the cost of transmission and improvement in the general characteristics. In FFTS, we use reduced frequency for transmission system and therefore losses in the form of corona discharge get reduced hence improving stability and performance characteristics.

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