

# Comparative Analysis of Performance of Fractional Frequency Transmission System with Conventional 50Hz System

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**Abstract**— A new promising approach to increase transmission line capacity is Fractional Frequency System which uses reduced frequency (50/3 Hz) which in turn reduces reactances of AC transmission line. This approach remarkably improves operating performance. In this paper, comparative analysis of performance of FFTS and conventional 50Hz line is presented. Performance is evaluated by using static power transfer equations in ABCD parameters of transmission line. Power transfer, Regulation and Efficiency curves are investigated by the algorithm code written in MATLAB.

**Key words:** FFTS, Long distance transmission, ABCD parameters

## I. INTRODUCTION

The AC electricity supplied by utilities has two basic parameters: voltage and frequency. After the transformer was invented, different voltage levels could be used flexibly in generating, transmitting, and consuming electricity to guarantee efficiency for different segments of the power system. In the history of electricity transmission, besides of 50–60 Hz, many frequencies were used, such as 25, 50/3, and 133 Hz. A 25-Hz electric system had been chosen as the winning design. However, since 50–60 Hz was selected as the standard, changing frequency apparently became taboo. The reason for this might consist in that to transform frequency is more difficult than to transform voltage. As new materials and power electronic techniques continuously advance, different kinds of large-frequency changers are developed rapidly. This trend may possibly lead to more reasonably selecting different frequencies for electricity transmission and utilization. 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 fractional frequency transmission system (FFTS) is a very promising long-distance transmission approach, which uses lower frequency (50/3 Hz) to reduce the electrical length of the AC power line, and thus, its transmission capacity can be increased several fold.

Xifan Wang, Xiuli Wang, “Feasibility Study of Fractional Frequency Transmission System”, suggested the Fractional Frequency Transmission System which uses lower frequency to reduce reactances of AC transmission system. This approach remarkably improved operating performances and increase transmission capacity. Practicability and Efficiency of the FFTS is studied by computer simulation method. For that purpose, a mathematical model and an algorithm is developed. A simulation result indicates that when exciting sources exist in both sides of the magnetic frequency changer, the

direction of the real power flow is reversible. This feature enables us to interconnect two power frequency systems through a FFTS, “IEEE Transaction on Power Systems, Vol. 11, No.2, May 1996”

Wang Xifan, Cao Chengjun and Zhou Zhichao, “Experiment on Fractional Frequency Transmission System”, proposed the main idea of boosting transmission capacity by reducing the power frequency. Experimental study achieved in Power System laboratory of the Xi’an Jiaotong University. Cycloconverter was used as the frequency modifier to step up 50/3 Hz Power to 50 Hz Power and later supply it to the utility grid. The results of experiment shows that a 1200km 500kV transmission line can transmit electric power to 2000 MW by using fractional frequency transmission system. Transmission capability increased 2.5 times than conventional 50 Hz transmission method. Experiment uses FACTS devices with great potential. On comparing with HVDC transmission, the FFTS can save an electronic converter terminal thus in turn reduces investment. FFTS can easily form a network like conventional AC system, “IEEE Transaction On Power Systems, Volume.21, No.1, February 2006”

YANG Quan-xin, WANG Wei, XU Li-jie, NI Ping-hao, XIA Ming-Chao WANG Lin, LIU Heng-lin, “Research On Wind Power Connected To Power Grid By Fractional Frequency Transmission System”, Wind power system connected to power grid through FFTS. The System is modeled and simulated with MATLAB Simulink. A result indicates that FFTS helps in reducing the size and weight of wind turbine and also reduce loss in transmission line. The wind turbine can quickly respond to the change of the wind for the smaller inertia thus can capture maximum possible wind energy and improve the efficiency of electricity generation of wind turbine units. Also due to use of synchronous generators, the reactive power compensation capacity of the system is greatly reduced.

Xifan Wang, Yufei Teng, Lianhui Ning, Yongqing Meng and Zhao Xu, “Feasibility of integrating large wind farm via fractional frequency transmission system a case study”, Feasibility of integrating large wind farm via FFTS is analyzed in this paper by a case study. Scheme A and B are designed to transmit 10GW wind power generated by the Jiu Quan wind base to the Lanzhou substation of North West China Power Grid. Scheme A adopts the conventional AC transmission system, while Scheme B adopts FFTS. Both power flow analysis and transient stability analysis illustrate that these two schemes satisfy various operational constraints. However, on a typical operation day, the voltage fluctuation reaches 7.46% for Scheme A and only 5.86% for Scheme B because the transmission system reactance of the latter is less than that of the former. This means Scheme B can receive more wind power than Scheme A. The economy study shows that Scheme B is better than scheme A. The

equivalent annual cost of Scheme B is less by 17.244–17.600% than that of Scheme A. The main reason for this result consists in that less transmission circuits and cheaper wind generators are used in Scheme B., “INTERNATIONAL TRANSACTIONS ON ELECTRICAL ENERGY SYSTEMS Int. Trans. Electr. Energ. Syst. 2014; 24:64–74,14<sup>th</sup> January 2013.”

In this paper, performance of the line is evaluated in terms of Active power transfer capability, Voltage Regulation and Efficiency by using static power transfer equations in ABCD parameters of transmission line.

## II. STUDY

In the FFTS, transmission line is operated at 50/3 Hz. Here decreasing the frequency ‘f’ can proportionally increase transmission capability. Performance parameters of transmission line i.e. Active power transfer capability, Voltage regulation and Efficiency are evaluated by using power flow equations.

Consider the two bus system shown in figure

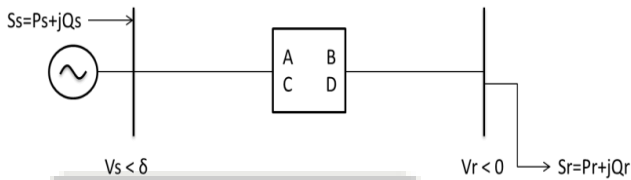


Fig. 2.1: Two Bus System

$V_s$ ,  $V_r$ ,  $I_r$ ,  $I_s$  are always per phase values along with angle.

$$\vec{V}_s = A\vec{V}_r + B\vec{I}_r \dots (2.1)$$

$$\vec{I}_s = C\vec{V}_r + D\vec{I}_r \dots (2.2)$$

Where,

$A = |A| < \alpha \rightarrow |A| \leq 1$ , very close to unity and  $\alpha = (0^\circ \text{ to } 10^\circ)$

$B = |B| < \beta \rightarrow$  Series Impedance of Transmission Line,  $\beta = (50^\circ \text{ to } 90^\circ)$

$C = |C| < \gamma \rightarrow$  Shunt Admittance of Transmission Line

$D = |D| < \Delta \rightarrow |D| \leq 1$ , very close to unity and  $\alpha = (0^\circ \text{ to } 10^\circ)$

The line performance equations in terms of receiving end and sending end complex power are,

$$P_R = \frac{|V_s| |V_R|}{|B|} \cos(\beta - \delta) - \frac{|A|}{|B|} |V_R|^2 \sin(\beta - \alpha) \dots (2.3)$$

$$Q_R = \frac{|V_s| |V_R|}{|B|} \sin(\beta - \delta) - \frac{|A|}{|B|} |V_R|^2 \sin(\beta - \alpha) \dots (2.4)$$

$$P_S = \frac{|D|}{|B|} |V_S|^2 \cos(\beta - \alpha) - \frac{|V_s| |V_R|}{|B|} \cos(\beta + \delta) \dots (2.5)$$

$$Q_S = \frac{|D|}{|B|} |V_S|^2 \sin(\beta - \alpha) - \frac{|V_s| |V_R|}{|B|} \sin(\beta + \delta) \dots (2.6)$$

Where A, B, C, D are generalized constants of long transmission line and given as;

$$A = D = \cosh \gamma l \dots (2.7)$$

$$B = Z_c \sinh \gamma l \dots (2.8)$$

$$C = \frac{1}{Z_c} \sinh \gamma l \dots (2.9)$$

$\gamma = \sqrt{zy}$  = propagation constant

$Z_c = \sqrt{\frac{z}{y}}$  = characteristic impedance of transmission line

The flowchart is developed as shown in figure

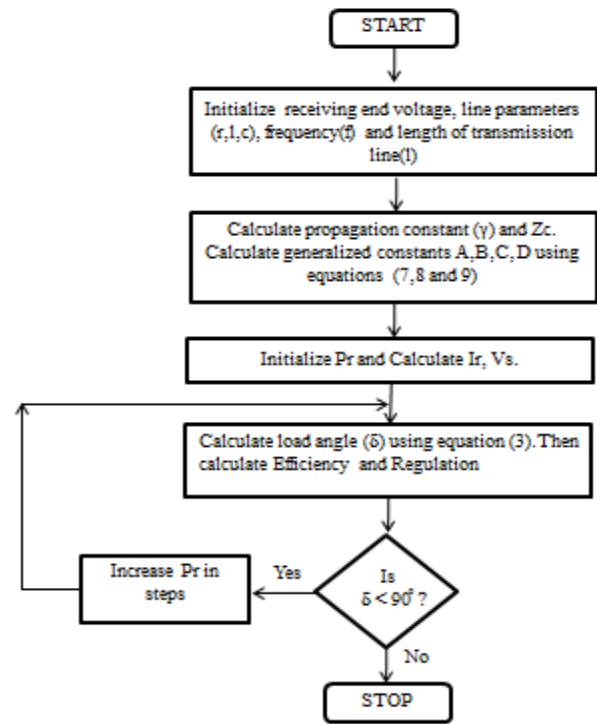


Fig. 2.2: Flowchart

## III. RESULTS AND DISCUSSION

Based on the algorithm shown in fig. code is written in MATLAB and executed for frequency of 50 Hz and 50/3 Hz with the the initialization of parameters as given below,

Voltage=220kV

Length of Transmission Line= 250 km

$r = 0.05 \Omega/\text{ph/km}$

$l = 1.294 \text{mH}/\text{ph/km}$

$c = 8.942 \text{nF}/\text{ph/km}$

$P_r = 50 \text{MW}$

### A. Power Transfer Curves:

The Power angle curves of FFTS and conventional 50Hz line is as shown in fig.3.1 From curves it can be seen that, power transferred across the line is more for FFTS line than conventional 50 Hz line for any operating condition.

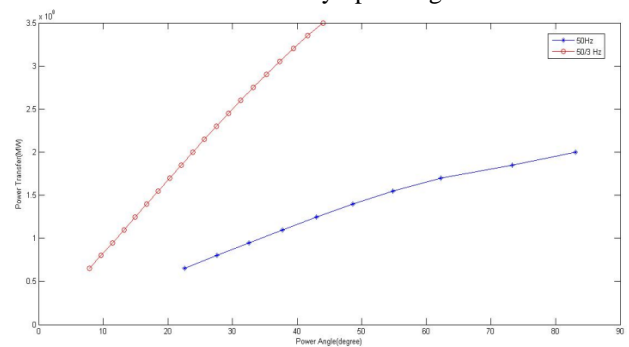


Fig. 3.1: Power Angle Curves of FFTS and Conventional 50 Hz Line

Results at different power angles are tabulated as follows;

50 Hz					
Delta(degree)	22.58	27.56	32.57	37.68	42.98
Pr(MW)	65	80	95	110	125

Table: 3.1

50/3 Hz					
Delta(degree)	22.06	23.85	25.67	27.51	29.38
Pr(MW)	185	200	215	230	245

Table: 3.2

From tabular result, for approximately  $\delta = 22^\circ$ , FFTS line transfers 185MW while conventional line transfers 65 MW. This indicates that power transfer is approximately 3 times greater for FFTS line than conventional line.

**B. Efficiency Curves:**

The efficiency curves of FFTS and conventional 50Hz line is as shown in figure. From curves it can be seen that, efficiency of FFTS line is more than conventional 50 Hz line for any operating condition.

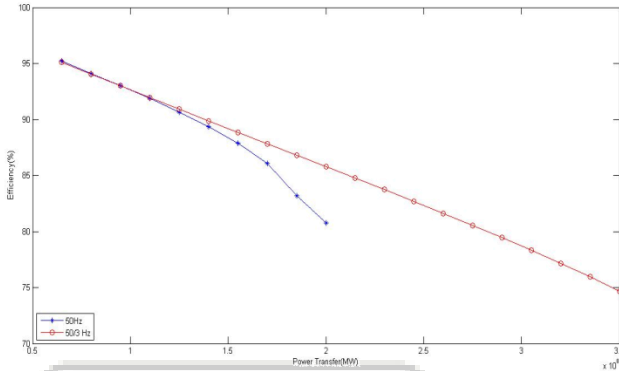


Fig. 3.2: Efficiency Curves of FFTS and Conventional 50Hz Line

Results at different Power transfers are tabulated as follows;

50 Hz					
Pr(MW)	110	125	140	155	170
$\eta$ (%)	91.87	90.67	89.33	87.88	86.07

Table: 3.3

50/3 Hz					
Pr(MW)	110	125	140	155	170
$\eta$ (%)	91.95	90.91	89.88	88.85	87.83

Table: 3.4

From tabular result, for the operating point corresponding to  $P_r = 110$  MW, efficiency of FFTS line is 91.95% whereas it is 91.87% for conventional line. So it is concluded that, the FFTS line has better(less) loss characteristics than 50 Hz line.

**C. Regulation Curves:**

The regulation curves of FFTS and conventional 50Hz line is as shown in figure. From curves it can be seen that, regulation of FFTS line is better than conventional 50 Hz line for any operating condition.

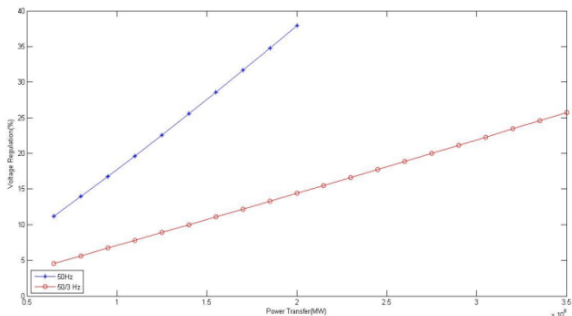


Fig. 3.3: Regulation Curves of FFTS and Conventional 50 Hz Line

Results at different Power transfers are tabulated as follows;

50 Hz					
Pr(MW)	110	125	140	155	170
Regulation(%)	19.64	22.57	25.55	28.58	31.65

Table: 3.5

50/3 Hz					
Pr(MW)	110	125	140	155	170
Regulation(%)	7.80	8.89	9.98	11.07	12.18

Table: 3.6

From tabular result, for the operating point corresponding to  $P_r = 110$  MW, regulation of FFTS line is 7.80% whereas it is 19.64% for conventional line. So it is concluded that, the FFTS line has better(less) voltage drop characteristics than 50 Hz line.

**IV. CONCLUSION**

The 50Hz and 50/3 Hz system is studied in this paper. From results obtained we can say that power transfer capability, efficiency and voltage regulation characteristics are better for FFTS line than 50Hz system. Thus this approach will be best alternative for the EHVAC or HVDC transmission system. Voltage profiles also get improved. In FFTS the receiving end voltage and power factor are within limits.

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