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Effect of Transmission Angle of Four Bar Mechanism of Automatic Transfer Switch in Transmitting Torque

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ABSTRACT

For efficient working of Transfer Switches, its four bar mechanism shall be robust enough with optimized design of links, transmission angle & torque. This paper deals with the effective force and motion transmission within four bar mechanism, which contains its output link as current carrying movable contact. So the speed of current carrying movable contact to separate out from its stationary contact needs to be maintained to reduce the possibility of production of arc, as high current passes through it. To transmit the optimum force to drive the mechanism, work is carried out on transmission angle of the mechanism. The paper contains the calculations regarding the improvement of existing four bar mechanism to achieve required linear velocity of current carrying link in minimum possible torque to avoid arc generation. Overall the working area of paper is an analysis and synthesis of mechanism.

***Keywords*— Automatic transfer switch, four bar mechanism, transmission angle.**

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I. Introduction

The automatic transfer switches are used where continuous use of electricity is needed, Such as corporate offices, hospitals etc. The generator sets are generally used as another reserve source as an option to the utility source. An automatic transfer switch transfers the power to generator set when utility source becomes unavailable. The generator set power is set to be available within short period of time. This work is carried out by transfer switch. When utility power becomes unavailable, generator set receives a signal from transfer switch and starts providing power as secondary source.

A.T.S. contains two main sections. One is actuator and operating mechanism and another is current carrying parts. In actuator assembly, solenoid gives the linear motion to the plunger. The plunger moves to operate the actuator to transfer the torque to the current carrying parts and its mechanism. In current carrying assembly, the four bar mechanism is working to carry and transfer the current. It is simply an open and close circuit which contains a Shaft as an input link, the rotation of which the mechanism will be in work. The mechanism further contains a movable contact which is connected with shaft with help of a coupler and input link. The movable contact carries the current. Its movement either opens the circuit or closes the circuit.

Generation of arc in the current carrying assembly of A.T.S., when carries the high magnitude of current, is the crucial issue of concern for the design engineers. So the internal mechanisms are necessarily be optimized and designed with required input such as velocity of movable contact and transmission angles of mechanism. Sufficiently high speed of movable contact as high magnitude of current flows through it, does not produce the arc. The arc may result in fire hazard and malfunction of transfer switch. The optimum speed of movable contact will help to quench the arc. So the hazards and malfunction of transfer switch are prevented.

The area of interest of the paper is to carry out the four bar mechanism calculations to obtain minimum torque to achieve required velocity of output link. Calculations mainly contain kinematic analysis and dynamic analysis of mechanism with calculations of transmission angles to achieve required velocity of movable contact with minimum torque

II. LITERATURE REVIEW

Balli S. S., Chand S., Transmission angle in mechanism. Mechanism and Machine Theory 37 (2002) 175-195.

This theory states that the transmission angle is an important criterion for the design of mechanisms by means of which the quality of motion transmission in mechanism, at its design stage is judged. It helps to decide the best among a family of possible mechanisms for most effective force transmission.

S. S. Rattan, Theory of Machines, 3rd Edition, Tata McGraw Hill Publication, 2009.

The book contains different methods for the analysis and synthesis of mechanism. Analytical and graphical methods to carry out the kinematic and dynamic calculations are elaborately specified. Vector method of analytical approach is used to carry out the calculations.

Transmission Angle

It is rather important to understand how the mechanism will function under loaded conditions in practice while the kinematic characteristics of the mechanism is being considered. By the performance of the mechanism we mean the effective transmission of motion (and force) from the input link to the output link. This also means that for a constant torque input, in a well performing mechanism we must obtain the maximum torque output that is possible and the bearing forces must be a minimum. Of course, torque and force are not the quantities those have been in the kinematics and whatever kinematic quantity we use to define the performance of the mechanism, this quantity will only approximate the static force characteristics of the mechanism. The dynamic characteristics, which are a function of mass and moment of inertia of the rigid bodies, may be several times more than the static forces and the behaviour of the mechanism under the dynamic forces cannot be predicted by kinematics. Still, some rule-of-thumb of the behaviour of the mechanism under load is defined by transmission angle.

III.OBJECTIVE

Improvisation of four bar mechanism for optimised velocity of output link with minimum input requirements.

IV.METHODOLOGY

The whole project is based on improvement of existing mechanism of automatic transfer switch which includes synthesis of mechanism both in terms of kinematics and dynamics.

The existing mechanism is improved in terms of maximum force transmission at minimum torque.

V.EXISTING DESIGN

I. A

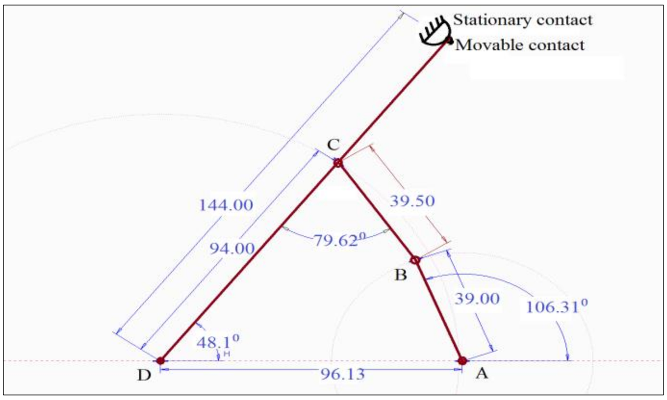

Fig. 1 Existing design

Existing design of the mechanism of transfer switch of industrial partner is taken into consideration.

For this, kinematic and dynamic analysis should be done with inputs as follows.

Transmission Angles:

1. $\mu max = 122.12^0$
2. $\mu min = 79.62^0$

Link lengths:

1. r1 = 96.13 mm = 0.09613 m.
2. r2 = 39 mm = 0.039 m.
3. r3 = 39.5 mm = 0.0395 m.
4. r4 = 94 mm = 0.094 m.
5. r4′ = 144 mm = 0.144 m.

Angular positions:

6. $\theta 1 = 0^0$
7. $\theta 2 = 106.31^0$
8. $\theta 3 = 124.54^0$
9. $\theta 4 = 48.1^0$

(r4′ is total length of link 4. Link 3 is attached to link 4 at distance of 94 mm of the link 4.)

A. Results

Results are obtained assuming output link rpm as 250 to 280 which is taken as example and kept unchanged for improved design for comparison with existing design. Here it is taken as 265 rpm. (Average of 250 and 280).

1) Kinematic Results

TABLE I

KINEMATIC RESULTS FOR EXISTING DESIGN

Link	n (rpm)	ω (rad/s)	a (m/s^2)	α (Rad/s^2)
r1	0	0	0	0
r2	1980.72	207.42	6289.06	155412
r3	-228.90	-23.97	6137.98	-155391
r4	265	27.78	286.385	2947.3
r4′	265	27.78	438.717	2947.3

2) Dynamic Results

Considering kinematic results as an input for dynamic analysis, results obtained are,

Inertia forces due to inertia of each link:
F1: 39.2824 N
F2: 211.9878 N
F3: 76.0544 N
Inertia torque on link 2: 11.4328 Nm anticlockwise.
Applied torque on link 2: 0.9297 Nm clockwise.
Total torque on link 2: 10.5030 Nm anticlockwise.
Torque on link 4: 6.9637 Nm clockwise.
Mechanical advantage: 0.6630.

3) Forces on Pin Joints

TABLE III
FORCES ON PIN JOINTS

Pin	Force	Value	Angle(Degree)
A	F_{12}	350.0334	219.18
B	F_{32}	311.1886	40.13
	F_{23}	311.1886	220.13
C	F_{43}	98.2695	219.69
	F_{34}	98.2695	36.69
D	F_{14}	170.8306	229.78

(Here, Fij is force acted by link i on link j).

VI. IMPROVED DESIGN

For break condition of movable contact of transfer switch, maximum force should come in effect to move the movable contact away from conductor with minimum torque requirement. If transmission angle is kept 90^0 at that position then above condition can be achieved. This requires some changes to be done in the mechanism itself to take care of space requirement and so as the movable contact should remain sufficiently away from the stationary contact of the circuit. One more requirement of industrial partner is to keep the length of output link unchanged

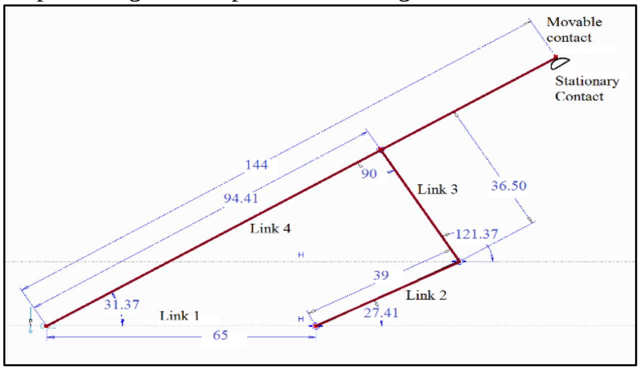

Fig. 2 Improveddesign

So the changes are also helpful to reduce the input torque requirement, made to the mechanism are given below,

Transmission Angles:
1. $\mu max = 90^0$
2. $\mu min = 68.29^0$

Link lengths:
1. r1 = 65 mm = 0.065 m.
2. r2 = 39 mm = 0.039 m.
3. r3 = 36.5 mm = 0.0365 m.
4. r4 = 94.41 mm = 0.09441 m.
5. r4′ = 144 mm = 0.144 m.

Angular positions:
6. $\theta 1 = 0^0$
7. $\theta 2 = 27.41^0$
8. $\theta 3 = 121.37^0$
9. $\theta 4 = 31.37^0$

A. Results

1) Kinematic Results

TABLE IIIII
KINEMATIC RESULTS FOR IMPROVED DESIGN

Link	n (rpm)	ω (rad/s)	a (m/s^2)	α (Rad/s^2)
r1	0	0	0	0
r2	643.72	67.41	320.29	6841.27
r3	-19.05	-2.05	85.46	-2340.41
r4	265	27.78	287.63	2947.32
r4′	265	27.78	438.72	2947.32

2) Dynamic Results

After performing dynamic analysis, results obtained are,
Inertia forces due to inertia of each link:
F1: 2.0006 N
F2: 19.287 N
F3: 76.0544 N
Inertia torque on link 2: 1.4367 Nm clockwise.
Applied torque on link 2: 2.9520 Nm clockwise.
Total torque on link 2: 4.3888 Nm clockwise.
Torque on link 4: 7.1634 Nm anticlockwise.
Mechanical advantage: 1.6322.

3) Forces on Pin Joints

TABLE IVV
FORCES ON PIN JOINTS

Pin	Force	Value	Angle(Degree)
A	F_{12}	36.8306	282.23
B	F_{32}	38.1790	104.48
	F_{23}	38.1790	284.48
C	F_{43}	54.4722	125.26
	F_{34}	54.4722	305.26
D	F_{14}	129.9675	131.53

VII. CONCLUSION

By the performance of the mechanism we mean the effective transmission of motion (and force) from the input link to the output link. This also means that for a constant torque input, in a well performing mechanism we must obtain the maximum torque output that is possible and the bearing forces must be a minimum. The project achieved the less input torque requirement for the same velocity of output link. Also bearing forces i.e. forces on pin joints are sufficiently lower to those for the mechanism with non-optimized transmission angle.

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