CHAPTER 6

DESIGN AND SIMULINK OF DC MOTOR PUMP

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6.1 INTRODUCTION

The Kyocera SD Series of submersible solar pumps are highly efficient, low voltage, DC powered, diaphragm type positive displacement pumps designed specifically for water delivery in remote locations. They operate on 12 to 30 volts of direct current that may be supplied from a variety of independent power sources including solar panels and/or batteries. Power requirements can be as little as 35 watts.

The DC motor pump chosen here for its size and cost is the Kyocera SD 12-30 submersible solar pump. It is a diaphragm-type positive displacement pump equipped with a brushed permanent magnet DC motor and designed for use in standalone water delivery systems, especially for water delivery in remote locations. Flow rates up to 17.0L/min (4.5GPM) and heads up to 30.0m (100ft.) [30]. The rated maximum power consumption is 150W. It operates with a low voltage (12-30V DC), and its power requirement is as little as 35W [69].

6.2 MODELING OF DC MOTOR PUMP

The flow rate of water in positive displacement pump is directly proportional to the speed of the pump motor which is governed by the available driving voltage. They have constant load torque to the pump motor, and it is expressed by the total dynamic head in terms of its equivalent vertical column of water. Figure 6.1 shows the relationship between flow rate of water and total dynamic head for the Kyocera SD 12-30 submersible solar pump to be modeled. It has the normal operating voltage 12-30V and the maximum power of 150W. Please refer the Appendix 1.6.
To model a permanent magnet DC motor, the SIMULINK model is given below.

6.3 SIMULINK MODEL OF DC MOTOR PUMP

To model a permanent magnet DC motor, the SIMULINK model applies a constant field, as shown in Figure 6.2. Since the water pump is a positive displacement type, the load torque is also constant; the value is selected to draw the maximum power of 150W at the maximum voltage of 30V. The parameters of DC machine, shown in Figure 6.3, that correspond to the actual pump motor are unknown, thus they are chosen by modification of the default values and estimation from other references [28]. The SIMULINK results are shown in Figure in 6.4 to 6.6.
Figure 6.2: SIMULINK model of DC motor pump

Figure 6.3: Parameters of DC Motor Pump.
Figure 6.4: SIMULINK curve $I_a$ vs. $V_a$ 

Figure 6.5: SIMULINK curve $T_e$ vs. $V_a$
6.4 CUBIC CURVE FITTING TOOL IN MATLAB

The Curve Fitting Tool in the MATLAB is an interactive environment presented in the form of a graphical user interface. It allows:

- Import data from the MATLAB® workspace
- Explore the data graphically
- Preprocess the data for fitting using exclusion rules and smoothing
- Fit a variety of library or custom models to the data
- Generate relevant regression statistics
- Post-process the fit through interpolation, extrapolation, differentiation, and integration
- Export results back to the MATLAB workspace for further analysis and visualization

Curve Fitting Toolbox

cftool: Open Curve Fitting Tool
SYNTAX

cftool

cftool(xdata,ydata)

cftool (xdata, ydata, w)

DESCRIPTION

cftool opens Curve Fitting Tool, an interactive environment for fitting curves to one-dimensional data.

cftool(xdata, ydata) opens Curve Fitting Tool with predictor data xdata and response data ydata. xdata and ydata must be vectors of the same size. Infs, NaNs, and imaginary parts of complex numbers are ignored in the data.

cftool(xdata, ydata, w) also imports the weight vector w into Curve Fitting Tool for weighting data in subsequent fits. w must be the same length as xdata and ydata.

6.5 CONVERSION OF RLC LOAD OF DC MOTOR INTO VOLTAGE DEPENDENT LOAD

From the above SIMULINK model as shown in Figure 6.2, the impedance curve is shown in Figure 6.7. The impedance curve is nonlinear or it means, it is RLE load but using the cubic curve fitting tool, it is converted into voltage dependent impedance as shown in the curve fitting tool output Figure 6.8. The equation of voltage dependent impedance load can be written as:-

\[
f(x) = P1(x)^3 + P2(x)^2 + P3x_o + P4
\]  

(6.1)

Where \( f(x) \) = Road

\[ x = V_o \text{(output voltage of converter)} \]

\[ P1 = 6.647 \times 10^{-5} \]
$P2 = -0.007382$

$P3 = 0.3574$

$P4 = 0.08488$

Putting these values into equation (6.1), we get

$$R_{load} = 6.647 \times 10^{-5} (V_0)^3 - 0.007382 (V_0)^2 + 0.3574 V_0 + 0.08488$$

.....(6.2)

Where

$$V_o = \frac{D}{1-D} V_s$$

Figure 6.7: SIMULINK curve of $R_{load}$ ($\Omega$)
6.6 CONCLUSION

The RLE load of DC motor pump is converted into voltage dependent load by Cubic Curve Fitting Tool. Now this load is dependent on the output voltage of CUK converter which is controlled by duty cycle (D). In the section 5.6, this load is matched by the input impedance load of CUK converter to get the maximum power transfer. Now this load is used in place of DC motor pump load in further application and design. It shows from the above SIMULINK results that the output current rises rapidly with increasing voltage until the current is sufficient to create enough torque to start the motor. Once it starts to run, the back emf takes effect and drops the current, therefore the current rises slowly with increasing voltage.