

Principle of operation of switched reluctance motor engineering essay



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1. INTRODUCTION:

From those days the variable reluctance motors had played a vital role in electrical field. These motors are very attractive because they have replaced conventional ac and dc drives in many industrial applications all over the world. Apart from the working they have many advantages such as simple and low cost construction. Since the variable reluctance motor has a high torque with the inertia ratio normal when compared with other motors. Eventually the single head salient synchronous reluctance motors have some advantages which are similar to variable reluctance motor. The cost and performance of the machine is highly dependent on the converter topology. The converter for the machine drive should be very fast accurate current control for better drive performance. In addition to these requirements the machine should produce low volt ampere rating for low cost, should be more reliable and robust with small number of switches producing high efficiency at last.

In addition to this all of these converters have greater switching loss and stress because the converters are all operated with hard switching. Now a day's soft switching is also implemented for these types of machines. The above mentioned goals can be achieved either by improving the machine design or innovation in the inverter configuration. I hope that my designing deals with the application of a particular type of inverter for the variable reluctance motor drive.

2. VARIABLE RELUCTANCE MOTOR DRIVES:

2.1 CONSTRUCTION:

The basic construction of switched reluctance motor is shown in the figure.

The construction includes both stator and rotor. It has six pole rotor and eight pole stator in it. The conventional variable reluctance motor that is nothing but the switched reluctance machine has a doubly salient laminated structure which is very simple and robust. The rotor does not contained any windings or conductors within it.

2.2 PRINCIPLE OF OPERATION OF SWITCHED RELUCTANCE MOTOR:

To start with the switched reluctance motor, the torque production in the machine is explained with the help of principle of electromechanical energy produced in the coil of the machine. As the rotor rotates, the inductance of the phase windings of a machine varies between the inductance values with respect to the rotor angle. Due to the highly nonlinear magnetic behaviour of the variable reluctance motor, the phase inductance is dependent on the current level as well as with the rotor position. There is also a speed dependent back emf that becomes very large below and above the base speed and dominates the behaviour of the drive. Although the machine has a simple structure, the behaviour of its electromagnetic is obviously convivial. The electrical input energy is given by expression which is displayed as follows;

However, the linear inductance of switched reluctance motor model along with back emf. And also the back emf is proportional to the machine speed which is very helpful in exploring the behaviour of this type of drive . The <https://assignbuster.com/principle-of-operation-of-switched-reluctance-motor-engineering-essay/>

diagram of solenoid coil and the characteristics of the machine is shown as below;

For low-speed operating mode, the back emf can be ignored in such a way that these can be compared with the dc bus voltage, and the machine can be assumed as current fed driving machine. Current fed operation is obtained by means of a current regulated pulse width modulation technique. With a proper controller and converter, the phase current should be designed to be close to a square waveform in order to minimize torque pulsations. The back emf increases for the medium speed range machine . To compensate the loss, phase is excited already in designing of the waveform . The machine runs at speed below and above the base speed.

Here the back emf is compared and also the emf is even larger than the supply voltage than that of the phase current. Thus the phase current becomes impossible without very large advanced techniques. The phase winding should now be excited before , whereas its inductance value is small in order to develop the sufficient current for a challenging torque. During this mode of operation the phase winding is fed with the voltage and hence the technique is called ' pulse dropping mode'. Even at any suitable power electronic converter or the controller, this type of drive system must maintain the capability of the design for the current pulses to maintain the values of variable reluctance motor accurately.

The above mentioned waveforms are executed by simulation method with the help of the mat lab software. The mat lab code for the above mentioned waveform is as follows;

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3. MATLAB SIMULATION:

3.1 CODING 1:

```
w= 1;
```

```
k= zeros;
```

```
d= 0;
```

```
z= zeros;
```

```
i= 0;
```

```
t= 0;
```

```
e= 0.000001; % is the increment of time
```

```
while (t <= 0.06)
```

```
if t <= 0.03
```

```
while i <= 6.5 % to limit the current to a maximum of 6.5
```

```
z(w)= t; % to store the time values
```

```
k(w)= i; % to store the current values
```

```
d=(1/0.1)*(100-(10*i))*e; % is the increment of current
```

```
i= i+d; % to increase the current
```

```
t= t+e; % to increase the time
```

```
w= w+1; % to increase the index of the current and time arrays
```

```
end
```

```
while i>= 6.5
```

```
while i>= 6 % to limit the current to a minimum of 6
```

```
z(w)= t;
```

```
k(w)= i;
```

```
d=(1/0.1)*(-(10*i))*e;
```

```
i= i+d;
```

```
t= t+e;
```

```
w= w+1 ;
```

```
end
```

```
end
```

```
end
```

```
if
```

```
t> 0.03
```

```
z(w)= t;
```

```
k(w)= i;
```

```
d=(1/0.1)*(-100-(10*i))*e;
```

```
i= i+d;
```

```
t= t+e;
```

```
w= w+1 ;
```

```
end
```

```
if
```

```
t>= 0.0353
```

```
break
```

```
end
```

```
end
```

```
plot(z, k,'r-','LineWidth', 2,'Color','black')
```

OBTAINED WAVEFORM:

3.2 CODING 2:

```
v=[]; % an array to store the value of voltages
```

```
p=[]; % an array to store the value of time
```

```
c=[]; % an array to store the value of the currents
```

```
R= 1; % resistance value
```

```
L= 0.001; % inductance value
```

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```
fs= 1000000; % sampling frequency
```

```
f1= 1000; % switching frequency of the 1st switch
```

```
f2= 142. 857; % switching frequency of the 2nd switch
```

```
d= 0. 5; % duty cycle
```

```
t_on= d*(1/f1); % t ON for the 1st switch
```

```
di= 0;
```

```
n= 0;
```

```
x= 0;
```

```
i= 0;
```

```
t= 0;
```

```
t2=(1/f2);
```

```
while t <=(0. 5*t2) % the first half cycle of the second switch
```

```
while (t <=(t_on+x)) && (t <= 0. 5*t2) % the period where the first switch is
```

```
ON
```

```
n= n+1;
```

```
v(n)= 50;
```

```
di=(1/L)*(v(n)-(R*i))*(1/fs);
```



```
i= i+di;
```

```
c(n)= i;
```

```
p(n)= t;
```

```
t= t+(1/fs);
```

```
end
```

```
x= x+(1/f1);
```

```
if (t <= 1/(2*f2))
```

```
while t <= x && (t <= 0.5*t2) % the period where the first switch is OFF
```

```
n= n+1;
```

```
v(n)= 0;
```

```
di=(1/L)*(v(n)-(R*i))*(1/fs);
```

```
i= i+di;
```

```
c(n)= i;
```

```
p(n)= t;
```

```
t= t+(1/fs);
```

```
end
```

```
end
```

end

while t>=(0.5*t2) % the second half cycle of the second switch

n= n+1;

v(n)=-50;

di=(1/L)*(v(n)-(R*i))*(1/fs);

i= i+di;

c(n)= i;

p(n)= t;

t= t+(1/fs);

if c(n)<= 0

break

end

end

plot(p, v), axis ([0 0.005 -50 55])

hold on;

plot(p, c)

hold off;

Xlabel (' Time')

Ylabel (' Current / Voltage')

OBTAINED WAVEFORM:

4. CLASSIFICATION OF SWITCHED RELUCTANCE MOTOR:

5. MODELING AND CONTROL STRATEGIES OF A VARIABLE RELUCTANCE MOTOR:

The above block diagram represents the modelling of the variable reluctance motor with their control strategy. The above circuit contains the following blocks such as feed forward compensator, flux or current controller and the driver block. The block also contains the observer. The feedback from the motor or drive is connected to the observer as well as to the feedback compensator. The machine is designed in such a way that it is based on both synchronous and asynchronous type and in this machine the torque control problem can be solved by transforming it into an equivalent current control one.

The simple solution is probable because the torque is proportional to the current or to a specific component of the current vector in a proper orientation system. Moreover by considering the wide availability of high-quality and low-cost current transducers the solution obtained is also more convenient from an economical point of view. For the variable reluctance motors the torque versus current function is nonlinear and therefore preventing the simple solution which adopt these drives for standard motors.

To prevail over the problem a cascade controller structure which is same as the one proposed earlier has been selected. It consists of an external static feed forward nonlinear compensator which is followed by a nonlinear flux or the current which is selected depending on design choices with the closed-loop controller. In the case of feed forward compensator transforms the torque set point which is corresponding to the flux or current is normal in these cases. The internal closed-loop controller is based on exact or directly measured feedback, depending on the controlled variable selected. Hence the optimization techniques are used for the design of a feed forward pre compensator.

The closed-loop controller operates in a stator reference frame thus by avoiding the use of match up transformations. This designing presents the inverter for the motor modelling and control optimization activities.

Importance is placed on the optimization techniques used in the design of the feed forward compensator. Finally the work related to the design of the closed loop flux or the current controller is currently in growth. The main report here is that the order to validate the design of the feed forward compensator. Previous to entering into details about the feed forward compensator design, some general considerations are value making in this kind of this design.

Direct calculation of a current set point is not suitable because the torque reliance on current must also think about magnetic nonlinearities. Even though the simpler relationship exists between torque and flux the feed forward compensator is designed under the assumption of an internal flux closed-loop controller. But the current is certain in such a way that the flux

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set point can be directly transformed into a current by means of the model output obtained. It must be pointed out how the planned replica structure would be greatly simplify the design of the torque controller.

A critical point is the alteration of the scalar torque demand into a corresponding three-phase flux vector. It can be noted that fluxes qualified to different phases can be bewildered independently by means of the associated control inputs. The control problem thus has as many degrees of freedom as the figure of phases. These degrees of freedom can be used for different purposes such as the four phase motor and the two adjacent phases. These are selected according to the real rotor position and torque signal that are used to impose torque dynamics and ripple-free operation.

The remaining two phases are controlled in order to keep their current at zero. For a certain phase motor, the required dynamics is obligatory on motor acceleration by controlling a single phase and thus by selecting as a function of position and torque sign. The left over controls must keep the remaining phase currents at zero or collect them to zero as fast as possible. Both approaches have the similar kind of problems mainly related to the need for a fast switch-on and switch-off of phase currents that impose a voltage waveform that is strongly impulsive.

While the voltage is limited in a real power inverter there is an increase in the enduring torque ripple occurs in the machine. Furthermore the solution proposed in during the good dynamic specification of the error between the actual and the desired acceleration does not control the torque ripple explicitly. The approach which is going to be considered in this attempt

many degrees of freedom as possible in order to get the best performance from the motor. Thus the modelling would be done in such a way that it gives high efficiency with the low cost production.

6. OVERVIEW OF A VARIABLE RELUCTANCE MOTOR TOPOLOGY:

The performance and cost of the variable reluctance motor drive is highly dependent on the topology used to drive the machine. Since the features of Variable reluctance motor drive have been realized the developments in the topologies have proceeded in parallel with the machine design. From those days there have been many topologies invented and while the conventional inverter driven induction machine drive the variable reluctance motor drives haven't been made standard . In addition to this the induction motor drives which almost always carry an pulse width modulation voltage link inverter . This method for variable reluctance motor drives seems to be much more application dependent. Ideally the variable reluctance motor drive should meet the following requirements:

capability to program a commanded current pulse very quickly and accurately for good drive performance.

Low noise and torque pulsation.

as low a converter power VA rating as possible for a given drive rating for low cost.

low switch/phase ratio.

reliability and robustness.

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high efficiency.

Only if all the above requirements are met then only variable reluctance motor drives can be comparable with the conventional inverter driven induction machine drive and other variable speed drives that are present in the market. These topologies discovered up to date and these materials have become popular and it is used in a many of the applications now a days. These configuration design include the asymmetric bridge converter with bifilar winding configuration which will split supply configuration from H-bridge configuration and also from the common switch configuration.

The asymmetric bridge converter has an entire current pulse programming power in such a way that the converter is able of apply the full supply voltage across the winding in either directions for the purpose turning the current in each phase that is in on state as well as in off state. Even though the converter faces some difficult from high switch or phase ratio it is normally expensive because the two switches per phase and the associated drive circuit.

The winding present in the machine that is the bifilar winding should meet the minimum switch requirement with one switch or the phase ratio. Thus the voltage waveforms resulting from non matching magnetic coupling will increase the switch voltage rating values to twice the value of the voltage and even higher. In addition to the losses such as copper loss which is associated with the auxiliary windings are generally high for many applications.

Thus the supply converter topology also meets the minimum switch requirement. And also in this case the phase number must be even and the converter does not ready to tolerate the phase unbalance or the fault in any phase. This is because these fault results in the voltage increase in the capacitor banks. And also the dc bus voltage utilization is poor because only $1/2K$ is utilized. Thus the H-bridge topology meets the minimum switch requirement. Therefore this reason is suitable for four or multiples of four-phase machines, and it also utilizes only half of the dc supply voltage. In this topology two phases are always on at one time and only one of the two phases are contributing to motoring torque production at any instant time.

Therefore, the degradation of the output torque is achieved easily. The common switch design in the machine only requires one more switch in addition to the minimum switch requirement. However this does not tolerate phase overlapping and therefore this leads to its capability and also this is very limited because for the particular reason for the single-pulse mode. Here in this method they have already used C-dump configuration design and this configuration design also requires only one additional switch to the one switch or the phase requirement.

The converter utilizes a capacitor to dump the energy of a switch off going phase and a chopper operating with buck principle to discharge the capacitance value. The capacitor voltage is generally maintained at twice the supply voltage value in order to supply negative supply voltage to the off going phase. The converter also has full capability to develop the current pulse during both turn on and turn off condition and also produces high

efficiency operation results at the end. The main disadvantages of this converter are the high switching device voltage ratings.

The cost of the additional switch of the dump capacitor and inductor also matters finally with the losses associated of the reactive elements. To open new application fields to the variable reluctance motor drives it is clearly necessary to both improve the drive performance at the lower cost. These goals can be achieved either by improving the machine design or creating some innovations techniques in the Inverter which we are going to design.

The general circuits for the converter topology are shown as follows;

The force production for motoring and regeneration waveforms is shown in the upcoming figure.

The forward direction of the motion of the translator is considered as the positive sign. The direction of the motion is considered as positive by assuming the certain phase sequence. While considering the forward direction of the motion they represent the forward motoring operations for their corresponding quadrants. Similarly when we are considering the reverse direction these regions represents the reverse regenerative operation for their quadrants. The duty cycle of each phase is only about 0.34 and their induced emf are constant between x_1 and x_2 . The air gap power and the generating electromagnetic force can be made constant by exciting the stator phases with the wide range of pulse of currents. The one half of the air gap power is saved in the phase windings in the form of magnetic field energy. Then the mechanical power output is formed from the other half of the air gap power. There is the similarities between the reluctance

motor and brushless DC motor in terms of current, air gap waveforms. Thus the dc machine controller can be used to control the switched reluctance motor for low cost and as well as for high volume applications.

7. ADVANTAGES OF A VARIABLE RELUCTANCE MOTOR:

Simple and robust in construction.

Low cost due to the absence of rotor windings and magnets due to the use of a small number of concentrated stator coils which is same as the field coils of a dc machine.

Low rotor inertia and high torque.

Motor phases operate almost independently to each other.

The machine has greater economy and reliability.

Machine does not need bi directional currents.

Suitable for high speed operations.

8. CONCLUSION:

Thus I hope that the back ground reading for my project has been done fully with the materials provided by our supervisor as well as with the materials we have collected. Future work is to design an inverter for a variable reluctance motor and build up the hardware kit for the operation. For the above mentioned reason I have gone through back ground reading completed related to the switched and variable reluctance motors. Thus my reason for taking over my project is for both modelling and building the <https://assignbuster.com/principle-of-operation-of-switched-reluctance-motor-engineering-essay/>

hardware is to simplify the design of the high performance inverter for the machine with high efficiency. Even though different approaches had been overcome to design an inverter the process is carried out to design the material for both rotating and linear machines. Up to date the designing of the material in the laboratory had been performed by simulating using the Mat lab software and coding and waveforms obtained are displayed above in our report.