

Exam 1

by Thomas Coombes

Submission date: 20-May-2022 04:16PM (UTC+0100)

Submission ID: 180972310

File name: 32993_Thomas_Coombes_Exam_1_421473_781078047.odt (17.52M)

Word count: 122

Character count: 560



Course: BEng Electrical and Electronic Engineering

Module: ACDA6004 Power Electronics & Drives

Exam 1

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Course year: 2021/22

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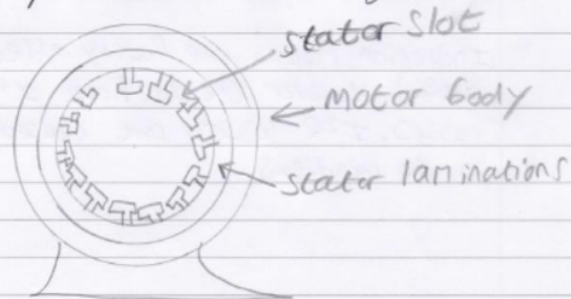
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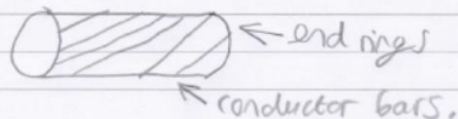
1) Working principles of an induction motor:

An Induction motor is made up of two key components; The rotor and the stator. The stator contains three coils separated by 120° . When the coils are energized this provides a rotating magnetic field (RMF) in the stator.

The stator typically contains steel laminations to reduce eddy currents. Stator diagram:



The rotor is made up of a Squirrel cage. The RMF in the stator induces a voltage in the rotor (Squirrel cage). Rotor diagram:



The Squirrel cage often contains small iron laminations to reduce eddy current losses. The Squirrel cage forms a closed circuit so current flows. This creates a magnetic field that opposes the stator RMF, therefore this force

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rotates the Motor and load. An induction motor relies on Slip, which can be calculated using the following Formula:

$$\text{Slip} = (N_s - N_r) / N_s.$$

where: N_s = Synchronous speed
 N_r = Rotor speed.

An induction motor is self starting. The speed may depend on the size of the load.

Induction motors are fairly efficient (sometimes more than 95%). However they do have I^2R and eddy current losses. I^2R losses are caused by the resistance in the windings.

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2) AS a solar panel increases in temperature, so does the resistance. As the resistance increases, the current drive ability of the solar panel also reduces. This reduces the efficiency of the solar panel, so to counter this natural variance/effect maximum power point tracking (MPPT) is used. MPPT can adjust the resistance in the solar PV inverter to maintain maximum transfer.

This is achieved by ~~re~~constantly measuring the voltage and current produced by the solar panel, then using this information to change the input resistance on the inverter to match the output resistance of the solar panel and ensure maximum power transfer.

There are several ways to achieve this, some common ones include:

- perturb and observe
- incremental conductance
- current sweep.

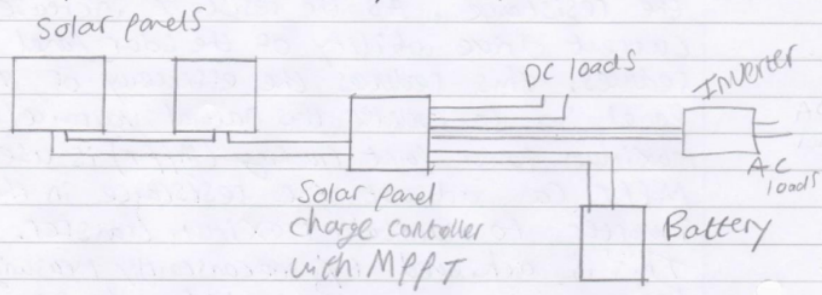
Perturb and observe method follows the above description, measuring the voltage + current then changing the resistance, if ~~a~~ output power increases then it will re-measure and adjust again.

MPPT is mainly used for solar panels, however it may also be used for wind turbines, optical power transmission and thermophotovoltaics.

Perturb and observe is the most common method due to it being easy to implement. It has high efficiency assuming a proper predictive and adaptive hill climb strategy is used.

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A typical off grid layout may look like this:



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$$3) \quad I = \frac{P}{V} = \frac{250,000}{6,000} = \underline{41.6A}$$

12 pairs of poles = 24 poles

$$f = \frac{WP}{60}$$

$$f_{min} = \frac{0 \times 24}{60} = 0 \text{ Hz}$$

$$f_{max} = \frac{1,000 \times 24}{60} = 400 \text{ Hz.}$$

therefore: $V = 6 \text{ kV}$, 41.6 A , $f = 0 \text{ to } 400 \text{ Hz}$. As the PWM contains 20 pulses per cycle the driving frequency of the transistors would be $0 \text{ Hz to } 8 \text{ kHz}$.

comparison table:

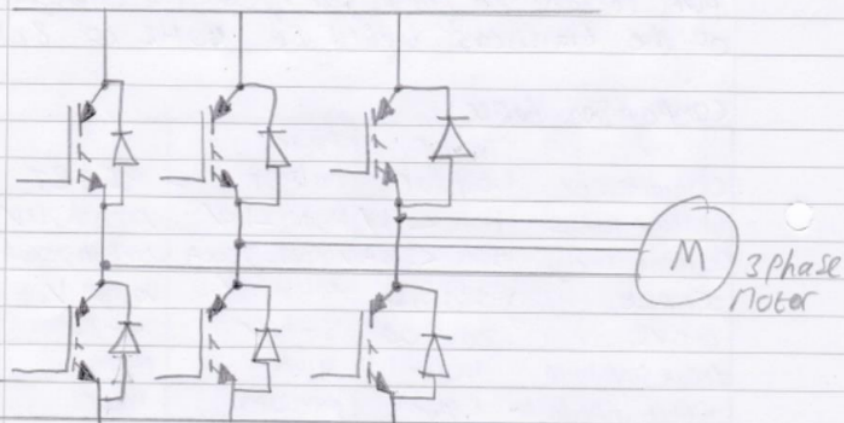
	power bipolar	power MOSFET	IGBT
Characteristic	bipolar	MOSFET	IGBT
Voltage rating	High $< 1 \text{ kV}$	High $< 1 \text{ kV}$	very high $> 1 \text{ kV}$
Current rating	High $< 500 \text{ A}$	very high $> 500 \text{ A}$	very high $> 500 \text{ A}$
Input drive	current ratio V_{BE}	voltage V_{GS}	voltage V_{GE}
Input impedance	Low	High	High
Output impedance	Low	medium	Low
Switching speed	Slow (μs)	Fast (ns)	medium
cost	Low	medium	High.

power bipolar and MOSFETS would not be suited to this application as the voltage is too high for these types of transistors.

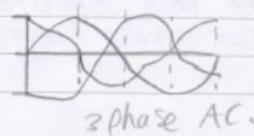
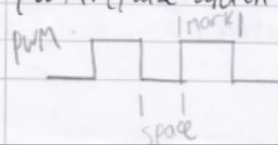
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This is the main limiting factor as the frequency of the switching speed and current are within the specifications for all three transistors.

Therefore due to the high voltage IGBT/insulated gate bipolar transistors would be the best technology suited for this application. The ~~IGBT~~ IGBT transistors would be connected in a push/pull configuration on each phase as per the diagram below. This would allow each phase to be connected to the positive supply or ground return path.

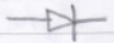


The gate drives for the transistors would be derived from a sinusoidal waveform encoded as PWM (pulse width modulation).



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- 4) VFD'S could use Diodes, SCR's or IGBT's for rectification. However they have various pros and cons highlighted below:

Diodes  (Used for 3 phase rectification)

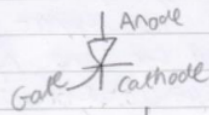
Pro

- cheap to buy
- Simple circuit design
- well established method.

Cons

- restricted with how much control you have on the output of circuit
- fixed DC output
- you can get a lot of noise/ripple ($6 \times \text{mains } 50\text{Hz} = 300\text{Hz}$).
- not smooth DC

SCR (thyristors)



Pro

- Provides basic control of voltage by changing firing angle.

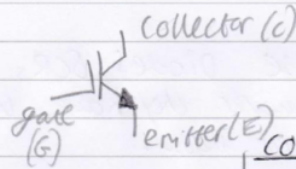
Cons

- more complex circuit (than diodes)
- extra circuitry required
- higher cost than diodes
- requires filters due to harmonics when cutting the waveform (such as low pass filter).

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IGBTspros

- can be used bidirectionally (for transmission and generation, useful for some applications such as ^{electric} cars).
- less noise than SCR

cons

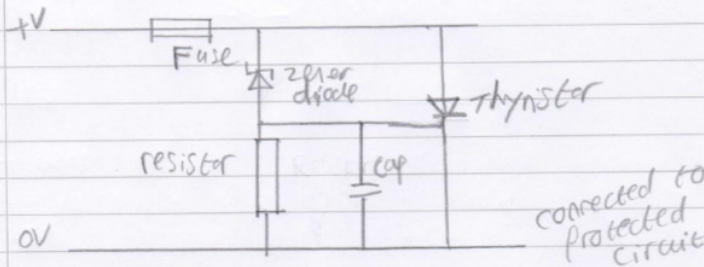
- Higher ^{mod.} cost compared to diodes + SCR
- Limited switching speed (can't do high speed applications)
- more complex circuit.

If cost wasn't a concern the IGBTs may be a more suitable method. However, several factors need to be considered such as circuit complexity, noise and switching speed.

IGBTs are able to support generation + transmission making them ideal for some applications such as electric cars. (regenerative braking).

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- 5) A thyristor can be used to provide over voltage protection for a DC power supply. A basic circuit may be as follows:



The circuit is connected to protect a specific circuit against over voltage, and keep the special smoke (inside smoke). This prevents damage to the attached circuit(s).

When the circuit is in normal operation the potential difference will not exceed the voltage specification rating of the Zener diode. Therefore the PD across the resistor is 0V.

If the potential difference exceeds the desired fixed limit (rating of the Zener diode), the over voltage will appear across the resistor. If this is steady/continuous then the capacitor will charge, therefore the thyristor gate voltage will increase and fuse the fuse will blow and protect the attached circuit. If there is just a noise or power spike the cap won't charge fully and conduct the thyristor.

Exam 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

96/100

Q1 - 13/15

Q2 - 25/25

Q3 - 25/25

Q4 - 18/20

Q5 - 15/15

Total 96/100

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