



Complete, fold and seal
(see note 2 below)

SURNAME: LOCKHART

FORENAME(S): DEREK

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either ignore illegible handwriting or have it typed and the expense of typing charged to the candidate.
4. Write your answers in ink.
5. Begin each answer on a fresh page. Do all rough work in the answer book and cross it through.
6. No part of this book is to be torn out; it must be handed in complete.
7. If more books than one are used, fasten them together using the tags available from the invigilator(s).
8. **Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.**

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

93.75%

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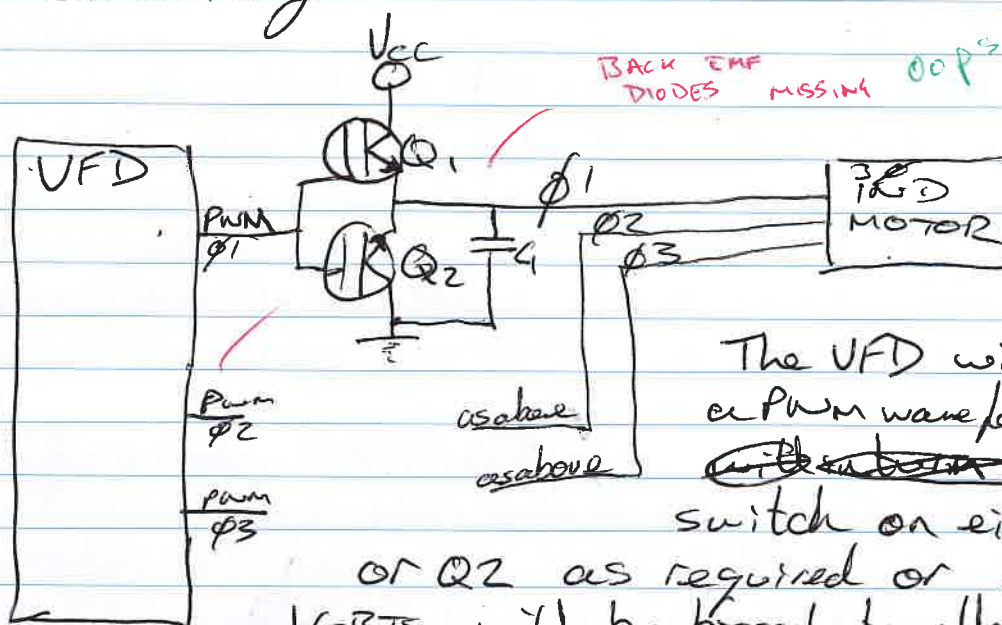
1. $P = 270 \text{ kW}$ 3ϕ Δ

$V = 25 \text{ kV}$ $f = 400 - 15 \text{ kHz}$

$$I = \frac{P}{V} = \frac{270 \text{ kW}}{25 \text{ kV}} = 10.8 \text{ A}$$

This application would be suitable for an IGBT device.

An ~~IGBT~~ insulated gate bipolar transistor is a device with a high input impedance and a low output impedance. The device is capable of good switching speeds (although lower than a MOSFET) it can handle very high supply voltages and high currents. Given the spec's this device will handle the current and voltage. The ~~low~~ ^{HIGH} input impedance will allow the circuit to be driven without a large driver circuit and the device requires very little support circuitry.



The VFD will provide a PWM waveform that ~~with a MOSFET~~ can switch on either Q1 or Q2 as required or not, the IGBTs will be biased to allow this to happen.

The freq of the PWM output from the VFD will determine the sync speed of the induction motor and the slip will determine the physical rotation speed difference from the sync speed. ✓

The VFD output of the PWM signals will be 120° separated

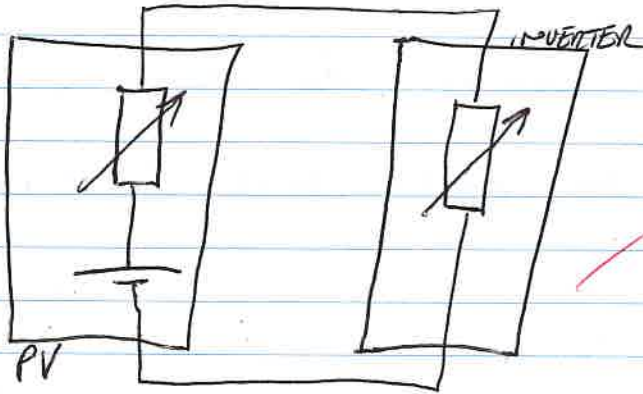
The outputs of Q1/Q2 will be smoothed by the reservoir capacitor C1 and present the required sine wave to the induction motor

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V. good

2. Maximum power transfer between any two devices is achieved when the impedances are equal. Therefore the variable output impedance of the solar panel must be found and matched by the input of the solar inverter.



As the solar panel's output impedance is dependent on temperature (and irradiance) the inverter must and is a non-linear relationship. The tracking design will also be non-linear.

The most common method is the Perturb and Observe (P+O) where the voltage will be adjusted and the effect on the power observed to find an increase in power transfer, as this is a 50/50 guess then the system will hunt and even after MPP has been found will continue to oscillate as it checks for a better solution for current conditions.

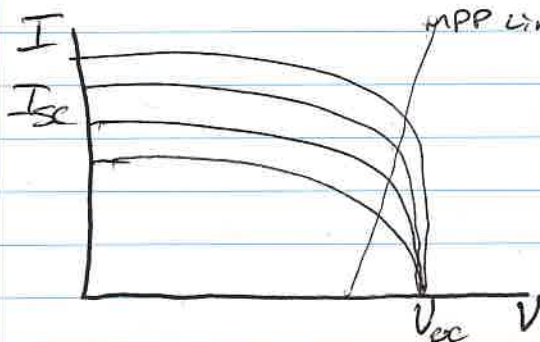
Therefore, as the solar panel temperature adjusts and its effective output impedance rises or falls the P+O method will hunt/hill climb looking for the maximum power available.

As the resistance of the solar panel and its matching to the input impedance of the inverter is critical to the max power transferred it can be quoted as the Fill factor (FF) which is the ratio of the maximum power compared to the product of the arrays open circuit voltage and short circuit current. This can be used

$$FF = \text{Max power} : V_{oc} * I_{sc}$$

as a guide to the efficiency of the MPPT Technique.

The maximum power point can be seen and modelled on the IV curve of the system where the value for predefined levels of irradiance/temp/resistance predict where the MPP is.



Other methods of tracking MPP include incremental conductance where the conductance ($\frac{I}{V}$) at set levels of current are modeled. This is another common hill climbing technique that can also produce oscillations. Other methods include current sweep and voltage step.

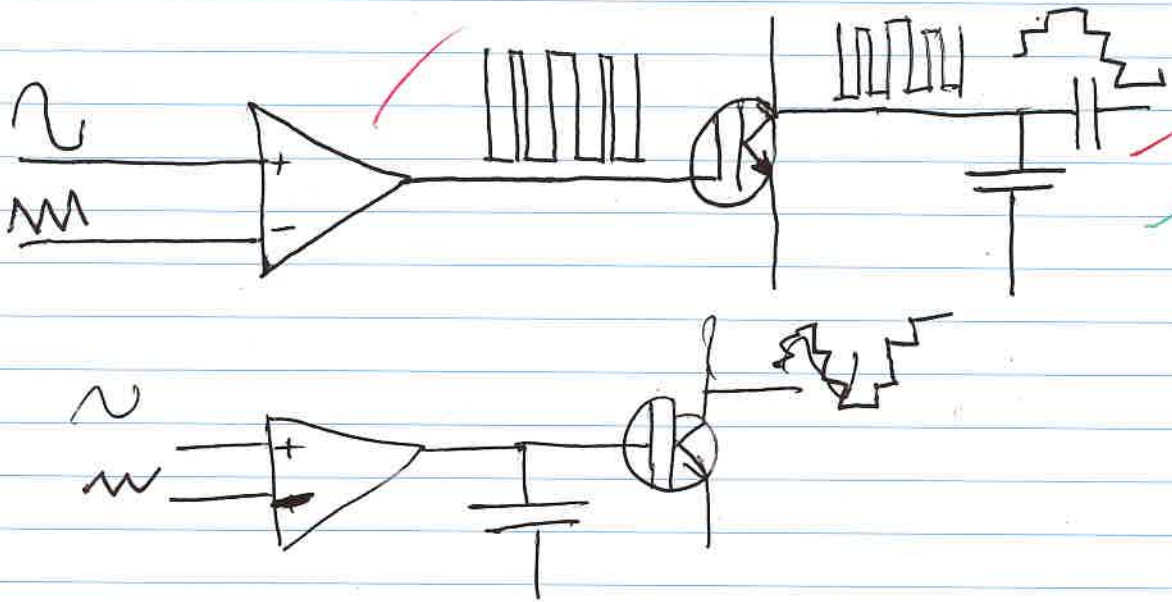
Current sweep involves remodelling the array at intervals and will have losses accordingly.

Voltage step. involves switching of the ~~same~~ output and induces losses/inefficiencies.

Excellent

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A simple PWM generating circuit can be derived from a comparator.

A sinusoid compared to a sawtooth on the inputs will provide an output of varying pulse width as the level of the sawtooth (its frequency determining the PWM sampling freq and therefore its accuracy) is compared to the sine wave whose freq will determine the eventual reproduced sine wave freq.

The PWM output is smoothed by the reservoir capacitor and this could be done before or after the IGBT although before the IGBT would require a smaller capacitor to smooth the signal.

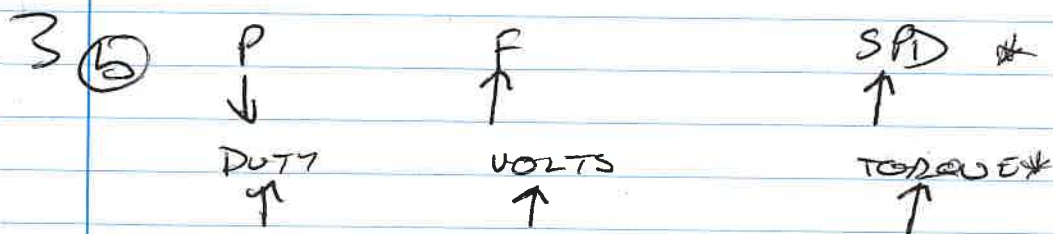
A further capacitor would be used to remove the DC level and pass the sine wave.

Further Filtering could be applied to

remove the harmonics that cause the square edge elements of the reproduced signal wave.

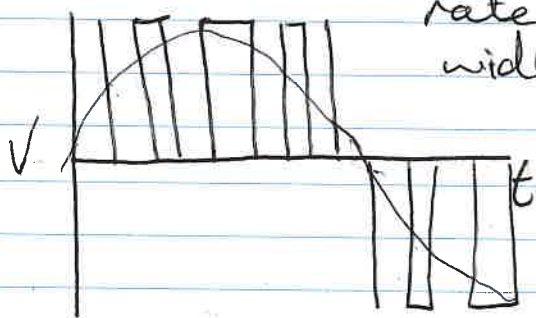
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As a synchronous AC motor rotates at the synchronous (supply) frequency then altering this supply frequency will alter the rotation speed. ✓

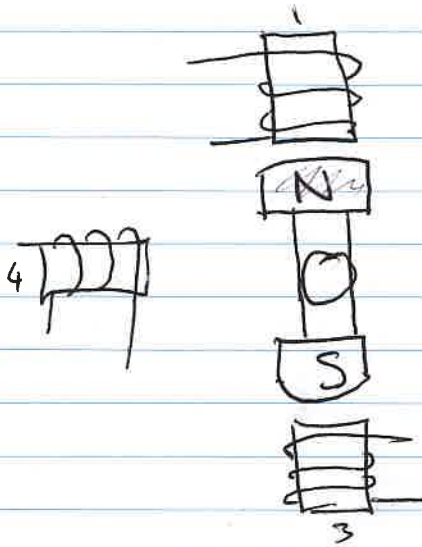
As the output frequency is a function of the rate at which the different PWM widths are changed then stepping through these options quicker will produce a higher output frequency to the motor. ✓



As the torque of the motor is a function of the peak voltage applied then the duty cycle of the PWM being increase will mean the peak voltage will be raised, this will increase the voltage average and the torque available from the motor. ✓

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L₁.

The permanent magnet in the rotor is attracted to the electromagnet of the opposite polarity.

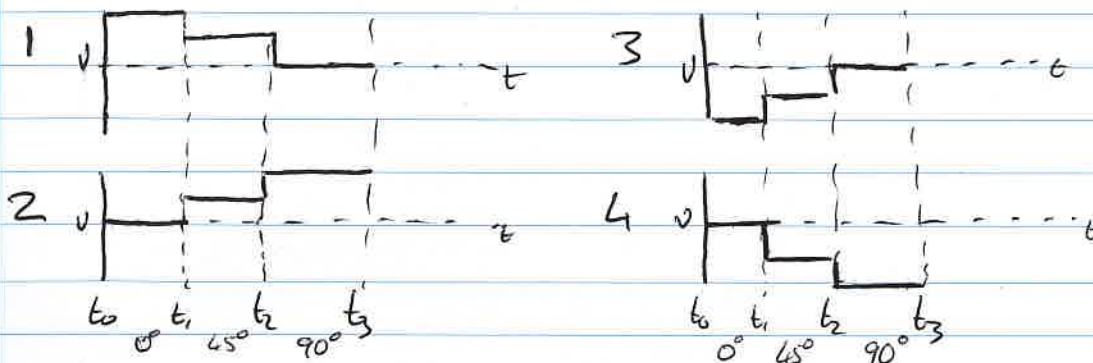
Therefore coil 1, being polarised as 'S' would step the motor toward it, this effect and the torque it

produces could be doubled. should at the same time coil '3' be polarised as 'N' to complete a step then coils 1 & 3 could be de-energised and coils 2 & 4 switched on in exchange this would produce a 90° step. ✓

Should coils 1 & 2 both be ~~set~~ excited to become 'S' then the rotor would step from illustrated position to 45°, this would be a half step. ✓

The electromagnets are polarised 'N' or 'S' by the direction of the current flow through them.

To switch from 0° (shown) to 90° via 45° step the following would be applied to the coils



This shows that if the waveforms continued the rotor could be made to complete 360° using 8 discrete steps.

This method can be extrapolated to create as many steps as is required ~~step~~ and dependent on the number of discrete voltage levels used (micro steps), 0.9° to 5° are common in stepper motors.

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