The Design Of An Electric Fence Monitoring System

A thesis presented in partial fulfilment of the requirements for the degree of Master of Technology in Production Technology at Massey University

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Abstract

This thesis presents the design of an Electric Fence Monitoring System (EFMS) which detects and announciates fence malfunctions indicating operational ineffectiveness.

The EFMS consists of a master unit and up to sixteen slave units. Each slave unit monitors a single remote point on the fence. Slave units gain their power from the electric fence pulse itself. They use a unique transmission algorithm to transmit the peak electric fence voltage, to the master unit. The electric fence wire is used to convey this transmission.

The master unit uses a non-linear switched capacitor filter with variable gain control, to detect the slave unit transmissions. This unit displays the peak voltage at each monitored point and allows the setting of alarm trigger points.

This thesis includes modelling of the electric fence energiser and typical electric fence line, and the detailed design of the two units that makeup the EFMS.

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Units And Symbols

Quantity	Symbol for Quantity	Unit	Symbol for Unit
Admittance	Y	siemens	S
Angular velocity	ω	radians/second	rad/s
Area	A	square metre	m^2
Capacitance	C	Farad	F
Charge	Q	Coulomb	C
Conductance	G	siemens	S
Current	I	Ampere	A
Energy	E	Joule	J
Flux	θ	Weber	Wb
Flux Density	B	Tesla	T
Frequency	f	Hertz	Hz
Impedance	Z	Ohm	Ω
Inductance	L	Henry	H
Instantaneous current	i	Ampere	A
Length	l	metre	m
Magnetic Field Strength	H	Ampere/metre	A/m
Number of turns on winding	N	(dimensionless)	
Period	T	second	s
permeability	μ	henry/metre	H/m
Power	P	Watt	W
Resistance	R	Ohm	Ω
Selectivity	Q	(dimensionless)	
Time	t	second	s
Voltage	V	Volt	V

The following prefixes are used in conjunction with the above units.

Prefix	Symbol	Fraction
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
kilo	k	10^{3}
mega	M	10^{6}

The following symbols are used throughout this thesis:

Quantity	Symbol for Quantity	Unit	Symbol for Unit
Propagation Constant	γ	(dimensionless)	
Transformer gap permeability	μ_{AIR}	Henry/metre	H/m
Transformer core permeability	μ_{CORE}	Henry/metre	H/m
Sample duration	Δt	second	s
Effective area of transformer core	A_l	square metre	m^2
Energiser storage capacitance	C_e	Farad	F
Electric fence capacitance	C_F	Farad	F
Electric fence capacitance	C_f	Farad	F
RFI suppression capacitance	C_S	Farad	F
Energy lost into inter-winding capacitance	E_{cap}	Joule	J
Energy lost in resistance of transformer windings	E_{copper}	Joule	J
Energy lost in resistance of transformer primary winding	$E_{copper.primary}$	Joule	J
Energy lost in resistance of transformer secondary winding	$E_{copper.secondary}$	Joule	J
Energy lost in diodes	E_{diode}	Joule	J
Energy lost in rectifier diodes	$E_{diode.rectifier}$	Joule	J
Energy lost in regulator diode	$E_{diode.regulator}$	Joule	J
Energy delivered into primary of transformer	E_{in}	Joule	J
Energy lost in resistance of inductor	$E_{inductor.wire}$	Joule	J
Energy lost in measurement components	$E_{measure}$	Joule	J
Transmission energy	E_T	Joule	J
Energy loss not attributable to one specific cause	$E_{transfomer}$	Joule	J
Filter centre frequency	f_0	Hertz	Hz
Filter clock frequency	f_{CLK}	Hertz	Hz
Power supply form factor	ff	(dimensionless)	
Transformer gap factor	G_F	(dimensionless)	
Filter output high pass gain	H_{OHP}	(dimensionless)	
Filter output low pass gain	H_{OLP}	(dimensionless)	
Filter output notch gain	H_{ON2}	(dimensionless)	
Power supply AC current	I_{AC}	Ampere	A
Power supply DC current	I_{DC}	Ampere	A
Transformer input current	I_{in}	Ampere	A
Transformer output current	I_{out}	Ampere	A
Peak current	I_{peak}	Ohms	Ω
Diode saturation current	I_S	Ampere	A
Chebyshev filter gain constant	K	(dimensionless)	

Transformer core magnetic path length	l_{CORE}	metre	m
Transformer gap length	l_{GAP}	metre	m
Transformer magnetising inductance	L_M	Henry	H
Slave unit power supply inductance	$L_{power.supply}$	Henry	H
RFI suppression inductance	L_S	Henry	H
Leakage Inductance of transformer primary	L_{T1}	Henry	H
Leakage Inductance of transformer secondary	L_{T2}	Henry	H
Electric fence inductance	L_W	Henry	H
Number of energiser pulses counted	m	(dimensionless)	
Number of data samples	N	(dimensionless)	
Number of energiser pulses	n	(dimensionless)	
Number of slave units	n	(dimensionless)	
Number of capacitive current data samples	N_C	(dimensionless)	
Number of falling output current data samples	N_F	(dimensionless)	
Number of rising output current data samples	N_R	(dimensionless)	
Transformer turns ratio	N_R	(dimensionless)	
Number of positive responses	p	(dimensionless)	
AGC resistance	R_{AGC}	Ohms	Ω
Ground Resistance	R_G	Ohms	Ω
Load Resistance	R_L	Ohms	Ω
Transformer core loss resistance	R_M	Ohms	Ω
Resistance of measurement components	$R_{measure}$	Ohms	Ω
Filter equivalent feedback resistance	R_N	Ohms	Ω
Transformer primary resistance	R_{T1}	Ohms	Ω
Transformer secondary resistance	R_{T2}	Ohms	Ω
Thevenin equivalent resitance	R_{TH}	Ohms	Ω
Electric fence wire resistance	R_W	Ohms	Ω
Resistance of transformer winding	R_{wire}	Ohms	Ω
Time taken for capacitor to charge	t_c	second	s
Transformer utilisation constant	TU	(dimensionless)	
Power supply AC voltage	V_{AC}	Volt	V
Voltage drop across transistor base emitter junction	V_{be}	Volt	V
Measurement capacitor voltage	V_c	Volt	V
Power Supply Voltage	V_{CC}	Volt	V

Power supply DC voltage	V_{DC}	Volt	V
Power supply rectifier diode voltage drop	V_{DIODE}	Volt	V
Power supply regulator voltage drop	V_{DROP}	Volt	V
Peak fence voltage	V_{fence}	Volt	V
Voltage drop across FET drain source	V_{FET}	Volt	V
Transformer input voltage	V_{in}	Volt	V
Maximum output voltage	V_{max}	Volt	V
Transformer output voltage	V_{out}	Volt	V
Peak transmission voltage	V_P	Volt	V
Voltage drop across pullup resistor	V_{pullup}	Volt	V
Measurement resistor voltage	V_r	Volt	V
Power supply ripple voltage	V_{Ripple}	Volt	V
Diode threshold voltage	V_T	Volt	V
Transformer voltage	V_T	Volt	V
Thevenin equivalent voltage	V_{TH}	Volt	V
Voltage across energiser	V_{Ze}	Volt	V
Shunt admittance per unit length	y	Siemens	S
Equivalent Admittance	Y'	Siemens	S
Series Impedance per unit length	z	Ohms	Ω
Equivalent Impedance	Z'	Ohms	Ω
Characteristic Impedance	Z_c	Ohms	Ω
Energiser impedance	Z_e	Ohms	Ω
Impedance of slave unit	Z_{slave}	Ohms	Ω