Cairo University

A TRAVELLING WAVES-BASED FAULT LOCATION SCHEME FOR MULTI-TAPPED OVERHEAD DISTRIBUTION SYSTEMS

By

Mahmoud Abd EL Fattah Mahmoud

A thesis submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

In

Electrical Power and Machines Engineering

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2017

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TITLE OF THESIS: A TRAVELLING WAVES-BASED FAULT LOCATION SCHEME FOR MULTI-TAPPED OVERHEAD DISTRIBUTION SYSTEMS

Key Words: Characteristic Frequency, Distribution Network, Fast Fourier Transform (FFT), Fault Location, Clarke transformation, Travelling Waves.

Summary:

In this thesis, a digital protection technique is implemented for MV overhead distribution network using voltage signals only at MV substation. The proposed scheme utilize an automation system which depends on installing fault passage indicators at strategic points to identify the faulted section. The exact fault distance is determined through two phases. The first one is representing the network by a set of equations. Each equation belongs to specific path and fault type; as a relation between the distance between substation and fault point and the generated frequency observed at the substation. The other phase is the substituting by the obtained frequency in the appropriate equation.

The proposed scheme is extensively examined on a typical 22 kV distribution network. Different faults are simulated at different positions on main feeder and laterals to evaluate the accuracy of the proposed algorithm not only for various fault resistance, inception angle, and load level but also in case of changing in network topology. The final results demonstrate accurate fault location estimation for distribution systems.

ACKNOWLEDGMENTS

First of all, thanks to Allah who supported and strengthened me in all of my life and in completing my studies for the Master of Science (M.Sc.) degree.

I would like deeply to express my thanks and gratitude to my supervisors; Prof. Dr. Mahmoud Gilany and Associate Prof. Dr. Doaa Khalil Ibrahim, Electrical Power and Machines Department, Faculty of Engineering, Cairo University for their faithful supervision, enormous efforts, and their great patience during the period of the research.

Finally, I would like to thank my family for their great inspiration, kind support, and continuous encouragement.

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- **Symbols**

C	:	Capacitance of line per unit length.
F_0	:	Flux (Wb-turn) at steady state.
G	:	Conductance of line per unit length.
I_0	:	Current through magnetizing branch at steady state in (A).
I_m	:	Modal current.
L	:	Inductance of line per unit length.
L_p	:	Transformer inductance in primary winding in (mH).
L_{sec}	:	Inductance of the secondary side of SATTRAFO model.
R	:	Resistance of line per unit length.
R_m	:	Resistance in magnetizing branch in (ohm).
R_p	:	Resistance in primary winding in (ohm).
R_{sec}	:	Resistance of the secondary side of SATTRAFO model.
t_{r1}	:	Arrival instant of V_{r1} at busbar R.
t_{r2}	:	Detected instant of V_{r2} at busbar R.
t_{s1}	:	Arrival instant of V_{s1} at busbar S.
t_{s2}	:	Detected instant of V_{s2} at busbar R.
V_m	:	Modal voltage.
V_{prim}	:	Peak voltage of the primary side of SATTRAFO model.
V_{r1}	:	Generated travelling wave propagates towards busbar R.
V_{r2}	:	Reflection travelling wave of Vr1 at fault point.
V_{s1}	:	Generated travelling wave propagates towards busbar S.
V_{s2}	:	Reflection of Vr1 at remote busbar R.
V_{sec}	:	Peak voltage of the secondary side of SATTRAFO model.
Z_c	:	Surge impedance.
Δt_{1-0}	:	Time difference between the arrival time of zero mode and aerial mode.
Δt_f	:	Arrival time difference between substation detector and the detector at terminal of the faulted line.
Δt_m	:	Time differences between local maximum of signal coefficients.

Δt_{mp}	:	Arrival time difference between two the measuring points.
F_n	:	Nyquist frequency.
F_s	:	Sampling frequency.
V_r	:	Reflected wave.
V_{rp}	:	Root mean square voltage of the primary side of the transformer.
V_{rs}	:	Root mean square voltage of the secondary side of the transformer.
Z_T	:	Transformer impedance.
Z_{c2} & Z_{c1}	:	Characteristic impedances on the either side of transition point.
f_{im}	:	Improved value of characteristic path frequencies related to fault point.
f_p	:	Characteristic frequency corresponding to specific fault distance.
l_b	:	Distance between the two busbars S and R.
l_f	:	Distance between the substation and the end of the faulted line.
l_m	:	Distance between two measuring points.
n_p	:	Number of times required for a travelling wave to propagate along path (p) before get again the same polarity.
t_1	:	Instant that the first generated wave due to fault point is observed at locator in second.
t_2	:	Instant that the first reflected wave from the fault point is observed at locator in second.
t_A	:	Instant that the first generated wave is observed at terminal A in second.
t_B	:	Instant that the first generated wave is observed at terminal B in second.
t_C	:	Instant that the wave is generated by closing the circuit breaker in second.
t_R	:	Instant that the reflected wave is observed at terminal A in second.
v_0	:	Velocity of the zero mode.
v_1	:	Velocity of the first aerial mode.
v_τ	:	Transmitted wave.
ρ_{ri}	:	Current refection coefficient.
ρ_{rv}	:	Voltage refection coefficient.
$\emptyset$	:	Generated magnetic flux.