Design and Verification of Network Theorem Kit (4-in-1)

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Abstract
Network theorems play a vital role in simplifying complex electrical circuits. This paper presents the design and development of a compact Network Theorem Kit that verifies Thevenin's, Norton's, Superposition, and Maximum Power Transfer Theorems. The kit is developed using basic electrical components such as resistors, DC power supply, and measuring instruments. Experimental results are compared with theoretical calculations and found to be approximately equal. The proposed kit is economical, easy to use, and highly beneficial for students to understand circuit analysis concepts practically.

Keywords: Network Theorem, Thevenin, Norton, Superposition, Maximum Power Transfer, Electrical Circuit

1. Introduction

Electrical network theorems are widely used in circuit analysis to simplify complex networks into simpler equivalent circuits. These theorems help engineers to calculate current, voltage, and power efficiently without solving the entire circuit repeatedly.
In traditional laboratory setups, separate circuits are required to verify each theorem, which increases complexity and cost. To overcome this issue, a compact 4-in-1 Network Theorem Kit is designed. This kit integrates multiple theorem circuits on a single panel, making it easy to perform experiments and improving students' practical understanding.

2. Objectives

- To design and develop a 4-in-1 Network Theorem Kit
- To verify Thevenin's, Norton's, Superposition, and Maximum Power Transfer Theorems
- To compare theoretical and practical values
- To reduce cost and space of laboratory setup
- To improve practical knowledge of students

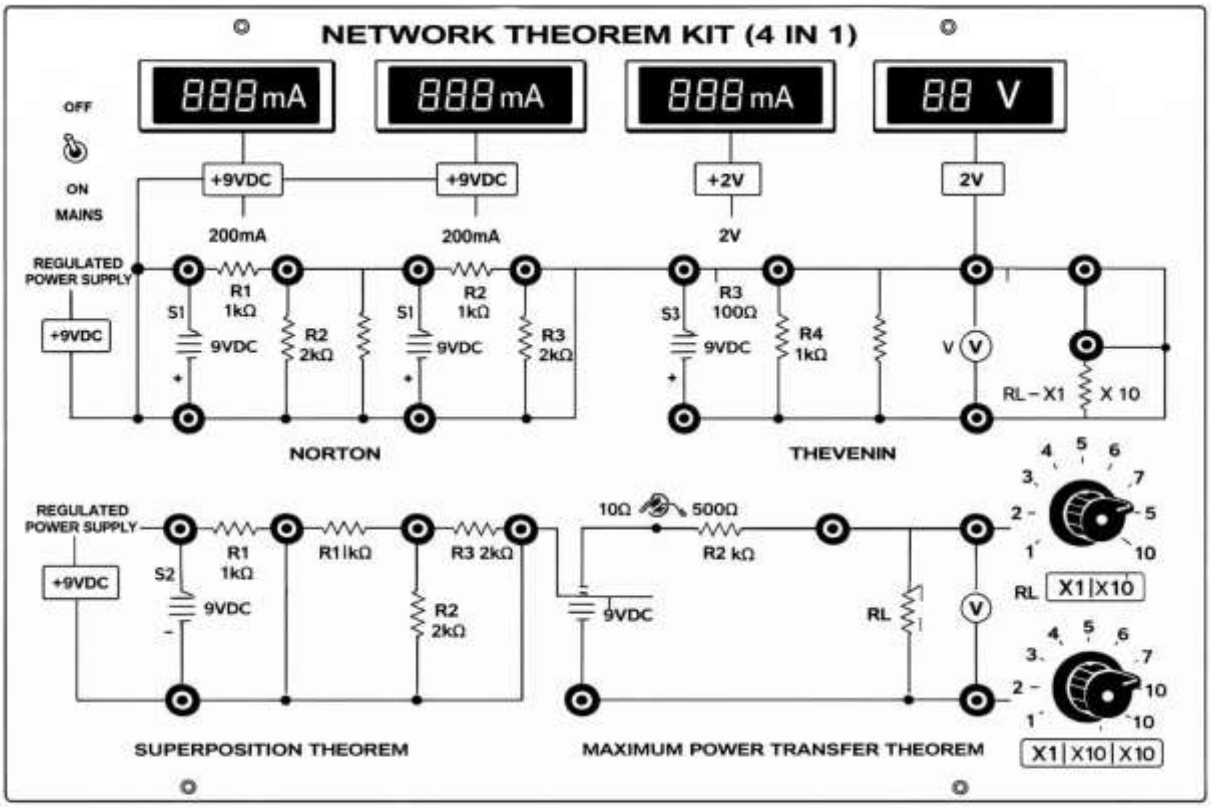
3. Methodology

The project is carried out in a step-by-step manner. First, the required network theorems are selected. Then, circuits for each theorem are designed using resistors and DC supply. Components are mounted on a panel board and proper wiring is completed. Switches are provided to select different theorem circuits.
The circuits are tested, readings are taken using measuring instruments, and results are compared with theoretical calculations.

4. Compound used

DC Power Supply (0–30V)
Fixed Resistors (¼W, ½W)
Variable Resistor (Rheostat)
Ammeter
Voltmeter
Switches (Toggle/Push Button)
Connecting Wires
Panel Board (Wooden/FRP)

5. circuit Diagram



5.1 Permanent Magnet Synchronous Generator (PMSG)

For VAWT applications, the PMSG is widely considered the optimal choice.

- **Direct-Drive Capability:** PMSGs can be designed with a high number of magnetic pole pairs, allowing them to generate nominal voltage and frequency at very low rotational speeds, eliminating the need for a gearbox.

- **Efficiency:** Without the need for an external excitation current (since the magnetic field is provided by permanent magnets like Neodymium), I^2R copper losses in the rotor are eliminated, resulting in higher overall efficiency.
- **Electrical Output:** The electrical power generated is expressed as:

Where V_{ph} is the phase voltage, I_{ph} is the phase current, and $\cos(\phi)$ is the power factor. The overall system efficiency η_{sys} is the product of the aerodynamic, mechanical, and electrical efficiencies: $\eta_{sys} = C_p \cdot \eta_{mech} \cdot \eta_{gen}$.

5.2 Power Conditioning and Grid Integration

Because the wind speed v is continuously fluctuating, the PMSG produces variable AC voltage and frequency. To utilize this power or inject it into the grid, a back-to-back converter system is required:

- **Rectification:** An uncontrolled diode bridge or active PWM rectifier converts the variable AC to a stable DC link voltage.
- **Inversion:** A grid-tied inverter converts the DC back to synchronized standard AC (e.g., 230V, 50Hz) suitable for local loads or the utility grid.

6. Proposed Methodology for Experimental Analysis

(Author's Note: For your actual publication, describe your specific setup here.)

To validate the theoretical models, a prototype VAWT coupled with a X-Watt PMSG will be tested under varying wind conditions using an artificial wind tunnel or anemometer- logged natural wind. Key parameters to be recorded include:

- Rotor RPM vs. Wind Speed
- Open-circuit voltage of the generator at varying RPMs
- Total electrical power delivered to a resistive load

7. Conclusion

Vertical Axis Wind Turbines offer a highly practical solution for localized, off-grid, and urban renewable energy generation. The mathematical and theoretical analysis indicates that pairing a lift-drag hybrid rotor with a multi-pole Permanent Magnet Synchronous Generator (PMSG) yields the highest efficiency. By utilizing a direct-drive PMSG topology, mechanical losses are minimized, and power extraction at low wind speeds is significantly enhanced. Future work should focus on optimizing the maximum power point tracking (MPPT) algorithms in the power conditioning circuitry to further improve grid integration.

References

1. Insert peer-reviewed paper on VAWT aerodynamics here.
2. Insert textbook/paper on PMSG design here.
3. Insert paper on Darrieus/Savonius hybrid designs here.