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SIMULATION OF ELECTRIC GRID AND ANALYSIS AT DIFFERENT CONDITIONS

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Abstract— One of the most serious issues in India is power theft. A significant amount of energy is lost as a result of power theft and poor management. As a result, it is necessary to design a system that can detect power theft as well as power theft location and make the necessary decision during normal and theft conditions without requiring any human interaction. This paper proposes a practical and cost- effective solution to the problem of power theft in distribution lines. A controller-based system is created that reads voltage and current readings from the LT side of the distribution transformer and household energy metres. The readings from the energy metre are transmitted wirelessly to the main control unit on the LT side of the distribution transformer. Based on the additional voltage drop and current in the distribution line caused by power theft, the power theft location can be determined. At the same time, the controller sends a signal to the circuit breaker to turn off the power and re-check for theft. If the theft is detected within four attempts, the system will be reinitialized; otherwise, an alert message with the theft location will be sent to the electricity provider or the nearest substation. The proposed system's MATLAB testing was found to be satisfactory.

Key Words - *Theft of power, distribution system, controller, circuit breaker, and theft location*

I. INTRODUCTION

In the field of network dynamics, power grids have long served as one of the main model systems motivating the study of synchronization phenomena [1–3]. As the field became more mature, an increasing number of researchers have been seeking to apply ideas from past theoretical studies to power grid-specific problems [4– 10]. The need for such applications comes from the fact that, despite the extensive engineering literature on power systems, there remains a largely under-explored problem of how the large-scale network structure influences the collective dynamics in power grids. While previous studies have emphasized the detailed modeling of relatively small test systems, the increasing availability of data processing tools, substantial computing power, and theoretical developments in network synchronization are now making it possible to address large-scale properties of power-grid systems. A major concern for power grids is the stability of desired states, in particular synchronization stability of the power generators, which is a condition required for their normal operation. A frequency-synchronous state of ng power generators is characterized by

$$\dot{\delta}_1 = \dot{\delta}_2 = \cdots = \dot{\delta}_{n_g},$$

where $\delta i = \delta i\ (t)$ is the angle of rotation associated with the ith generator at time t. Studying the stability of synchronous states of an alternating current interconnection against perturbations requires a network model capable of describing the coupled dynamics of power generators. Different models have been used in different publications in the physics literature, and there has been no comprehensive comparison to clarify how these models are related to each other. Providing such a comparative analysis is the main focus of this article. Here, we discuss three leading models, which we refer to as the effective network (EN) model [8, 11], the structure-preserving (SP) model [12], and the synchronous motor (SM) model [13]. Each model is described as a network of coupled phase oscillators whose dynamics is governed by equations of the form

$$\frac{2H_i}{\omega_R}\ddot{\delta}_i + \frac{D_i}{\omega_R}\dot{\delta}_i = A_i - \sum_{j=1, j\neq i} K_{ij} \sin\left(\delta_i - \delta_j - \gamma_{ij}\right),$$

Where ωR is a reference angular frequency for the system, and Hi and Di are inertia and damping constants characterizing the oscillators, respectively. The differences in the three models are reflected in the definition of the parameters Ai,Kij, and γij, as well as in the number of phase oscillators. The phase angle δi of oscillator may represent either a generator or load. While all three models represent the ng generators as oscillators, they are distinguished mainly by their different modeling approaches for the loads, which are representations of individual or aggregated consumers that draw power from specific points in the (transmission) network.

The EN model represents the loads as constant impedances rather than oscillators, thus focusing on the synchronization of generators as second-order oscillators. The SP model represents all load nodes as first-order oscillators (i.e., Hi = 0), and each generator is represented by two oscillators, including one for its terminal (a point connecting the generator to the rest of the network). The SM model assumes that the loads are synchronous motors that are represented as second-order oscillators. Figure 1 shows a simple example network that illustrates how these differences lead to different network dynamics representations with different number and values of model parameters. Note that the parameters are denoted in the figure using appropriate superscripts (EN, SP, and SM), which is a convention we will use throughout the article. The parameter Ai, along with Di, determines the ith oscillator'sinherent frequency,ω ω i * : (1) = + R ii A D , which is the equilibrium frequency of oscillatori in the absence of the coupling term (the summation term in equation (2)). For generators, this frequency is typically much higher than the system reference frequencyωR, as the two terms on the r.h.s of equation (2) balance each other in a steady state. In a realistic setting, however, the instantaneous frequency of a generator is unlikely to actually reach this inherent frequency, since the system operator would take control actions well before the frequency deviates too far from the designated system frequencyωR. In addition, the equation of motion for generators and motors we derive below assumes that the frequency remains close toωR and thus would no longer be valid if the frequency deviates too far from ωR. Nevertheless, this definition of inherent frequency can be useful in characterizing the nature of individual oscillators and, in fact, is analogous to the one usually used in studying networks of coupled phase oscillators. Note that 'natural frequency' is a term commonly used to refer to ωi * in that context, but it has a very different meaning in the power systems literature; see appendix. The parameter Kij ⩾ 0 represents the strength of dynamical coupling between oscillator si and j, while γij represents a phase shift involved in this coupling. Similar forms of second-order equations for coupled oscillators have been used to study synchronization and phase transitions outside the context of power grids [15–18].

II. RELATED WORK

As mentioned earlier, the energy systems development life-cycle can be divided into four different stages—the preliminary, detailed engineering design, implementation, and the post-implementation phases [8]. These include tasks from the preliminary assessments to obtaining of data from the users at the sites, detailed design based on the data obtained, physical implementation of the design, to the issues associated with the energy system after it has been implemented, such as operation and maintenance, capacity building, etc. The implication of this is that it is one thing to conceptualize, plan, design, and install energy systems, and it is another important thing to be able to sustain them to achieve long term viability and use. Therefore, the sustainability dimensions, i.e., the social, technical, economic, environmental, and policy, have to be adequately considered when planning energy systems, which are constituent parts of the phases mentioned above. The detailed engineering design phase involves modelling, simulation, and analysis of energy systems.

The complexity of the problem to be solved is expected to determine the nature of simulation and analysis and the software/tools to employ for the task. Considerations for sustainability in simulation and analysis imply that more parameters and factors are integrated, either directly or indirectly, in the process beyond the traditional techno-economic planning perspective. Apart from determining the users' load demand profile, type of energy technology-solar PV, wind, hydro, biomass, biogas, etc. initial cost, net present cost, and the O and M cost, it is also necessary to figure out some critical aspects of the social, environmental and policy dimensions; these include the status and class of the users, willingness to pay for the energy

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service, revenue generation from using and maintaining the energy service, ownership of the system, incentives associated with the creation and/or use of the service, environmental impact, end-of-life management of the system, etc. These parameters are crucial when proposing energy systems, and the question is how to integrate the parameters in a simulation. This paper will contribute to knowledge in this regard by considering the social, technical, economic, environmental and policy (STEEP) dimensions in the simulation and system analysis, from the sustainability perspective.

A typical simulation process includes the input parameters fed into a software (with in-built mathematical models and functions) to generate the output results. The input parameters involve the necessary data that the simulator will process, while the simulation tool has in-built equations, functions, and algorithms to process the input data. The outcome of this exercise is presented as the output results, which will then be analyzed for decision-making purposes. This represents a generic basis for the simulation framework that will be introduced in the later section of this research paper, which will capture a range of perspectives and situations from the users' point of view. The standpoint of this study is that the software or simulation tool has a crucial role to play in planning and designing sustainable energy systems. The problem to be solved will determine the type of software and tools to be employed based on the requirements.

III. EXISTING METHOD

In existing System power theft there are various existing system using GSM , Wi-Fi, WiMAX, ZigBee &Bluetooth(Short distance)Technologies , using IoT and Neutral Network , Fuzzy logic based system & IR sensor based system. But these all systems are not much efficient.

IV. PROPOSED SYSTEM

The proposed method is Power theft and its location can be determined by calculating the voltage drop and additional current flow in the distribution line as a result of power theft. If the theft current exceeds the allowable limit, the controller takes immediate action. The system makes the necessary decision to prevent external tapping in distribution lines based on the theft condition.

a) Mathematical analysis

Consider the distribution system depicted in Fig. 1. The voltage on the LT side of the distribution transformer is denoted by (Vs), and the voltage on the load terminal is denoted by (Vl). Because of the connected load, current (Is) will flow in the circuit. External tapping at a distance of Lth metre (theft distance) from the distribution transformer results in an additional flow of current (Ith) in the circuit as a result of power theft.

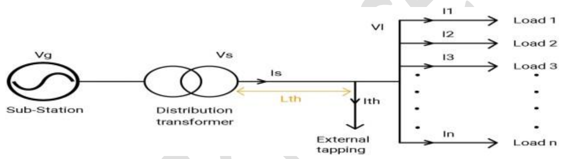

Figure 1: shows an example. The current (Is) is the total of all load and theft currents (Ith).

$$Is = [I1 + I2 + I3 + \ldots\ldots\ldots + In] + Ith \quad (1)$$

$$Is = \sum I + Ith \quad (2)$$

Theft current(Ith) can be calculated as: $Ith = Is - \sum I$

Working conditions :

a) Normal condition: (Is) is equal to sum of all load currents.

$$Is = \sum I \ (4) \quad Ith = 0 \quad (5)$$

$$\Delta V = Vs - Vl \quad (6)$$

Impedance of distribution line (Z): $Z = \Delta V/Is$ (7)

b) Theft condition: (Is) is greater than the sum of all load currents.

$$Is > \sum I \quad (8)$$

$$Ith \neq 0 \quad (9)$$

The voltage difference (ΔV^*) between secondary of distribution transformer (Vs) and load terminal (Vl) during theft condition

$$\Delta V^* = Vs - Vl \quad (10)$$

Voltage drop due to theft

$$Vth = \Delta V^* - \Delta V \quad (11)$$

$$Vth = Ith \cdot Zth = Ith\ ((\rho.Lth)/a) \quad (12)$$

Where (ρ) is the resistivity of material used in distribution line and (a) is the cross-sectional area

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of conductor. Theft distance from distribution transformer

(Lth): Lth = (Vth . L) / (Ith . Z) (13)

Where (L) is the overall length of the distribution line

c) Working Flow chart

The working of the proposed system can be easily understand by the flow chart as shown in Figure Below.

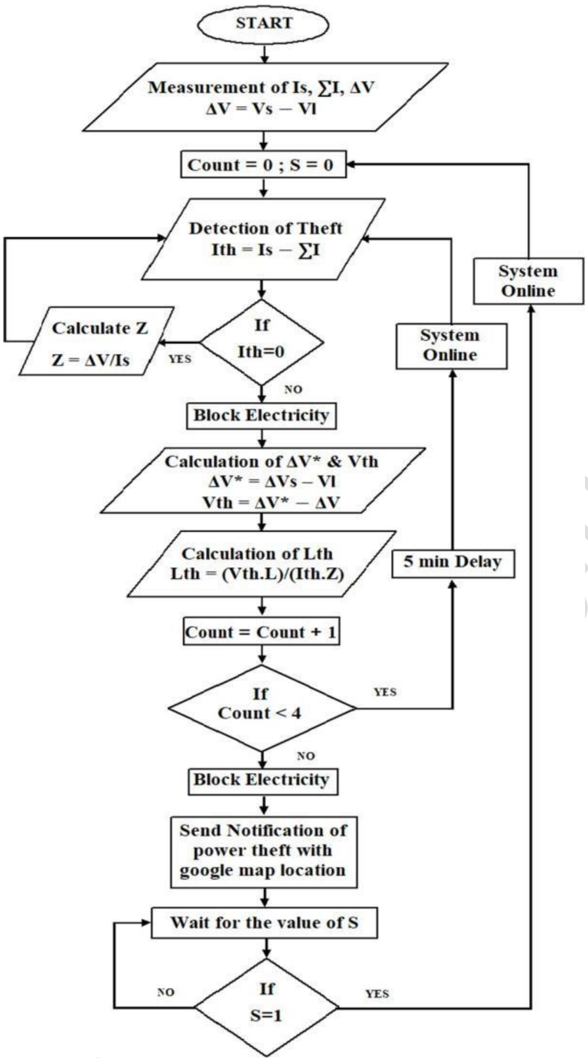

Figure 2: Flow chart of working of proposed system

d) Matlab Simulation

Figure 3 depicts the development of a power theft location detection system using MATLAB software. The distribution line is assumed to be divided into four equal parts with the same resistance value and length. Using a power theft location detector, an artificial theft (external tapping) is created to measure and verify the various values of theft distance.

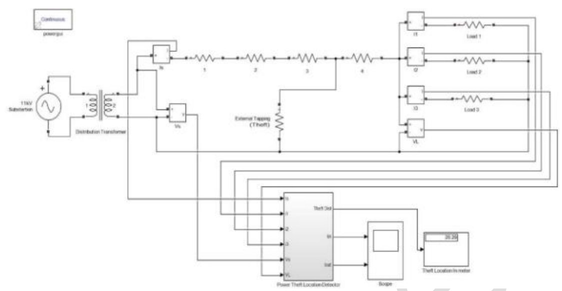

Figure 3: Simulation model of Power locate detection system on MATLAB software

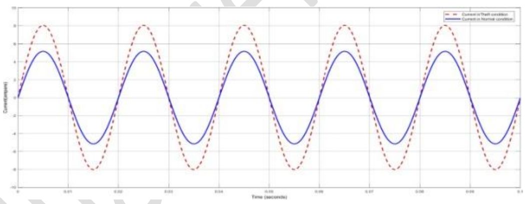

Figure 4: Current comparison during(Theft condition Vs Normal condition

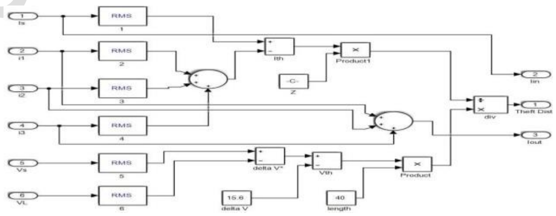

Figure 4: Design of power theft location detector on MATLAB software

Table I. Simulation Specification

Serial No	Simulation Parameters	
	Parameters	*Value*
1	Length of distribution line(L)	40 m
2	Load 1	100 ohm
3	Load 2	200 ohm
4	Load 3	300 ohm
5	Theft Load	100 ohm
6	Nominal power rating of distribution transformer	17000 VA
7	Primary voltage of distribution transformer	11000 V
8	Secondary voltage of distribution transformer	220 V
9	Operating frequency	50 Hz

V. RESULTS

The current comparison during theft and normal conditions, as well as the design of the power theft location detector/controller, are depicted in Figs. 4 and

5, respectively.

A. Normal Situation

- Total Load current (I) = 3.909 A
- Distribution transformer secondary voltage (Vs) = 220.000 V
- Load terminal voltage (Vl) = 204.400 V
- Normal voltage drop (V) = 15.600 V
- Distribution line impedance (Z) = 3.989 ohm

B. Theft situation

The corresponding theft location from the distribution transformer is obtained by changing the different tapping points via the designed controller.

Table II: Output of Power Theft Location Detector

Serial No.	Controller Results			
	Tapping point	**Actual theft location**	**Theft location from controller**	**Percentage error**
1	No tapping	0.00 m	0.00 m	0.00%
2	1,2	10.00 m	9.52 m	4.80%
3	2,3	20.00 m	18.87 m	5.65%
4	3,	30.00 m	28.21 m	5.97%

VI. CONCLUSION

The proposed system is capable of resolving the most common issue of power theft. It communicates data over a wireless network, which improves the system's reliability and effectiveness. The system is based on real-time detection, and the location of power theft can be easily determined using the received data, which includes current and voltage readings.

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