
An Optimum Solution for Electric-Power Theft

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ABSTRACT

Electric power theft is a problem that continues to plague power sector across the whole country. Every year, the electricity companies face the line losses at an average 20-30% and according to power ministry estimation WAPDA companies lose more than Rs. 125 billion. Significantly, it is enough to destroy the entire power sector of country. According to sources 20% losses means the masses would have to pay extra 20% in terms of electricity tariffs. In other words, the innocent consumers pay the bills of those who steal electricity. For all that, no any permanent solution for this major issue has ever been proposed. We propose an applicable and optimum solution for this impassable problem. In our research, we propose an Electric power theft solution based on three stages; Transmission stage, Distribution stage, and User stage. Without synchronization among all, the complete solution can not be achieved. The proposed solution is simulated on NI (National Instruments) Circuit Design Suite Multisim v.10.0. Our research work is an implicit and a workable approach towards the Electric power theft, as for conditions in Pakistan, which is bearing the brunt of power crises already.

Key Words: Electric, Power, Theft, Transmission, Distribution, User, Modulation, Smart, Meters.

1. INTRODUCTION

Electrical energy is very imperative for everyday life and a spine for the industry. The transformation of Electric power generated at power plant is based on the stages of Transmission, Distribution, and Utilization. There are two types of losses in electrical power distribution network "Technical losses" and "Non-technical losses". On account of structure and characteristics of network Technical losses occur, while Non-technical losses occur due to the stealing of electricity. Electric-power theft is an uncontrollable problem in third

world countries. It is a pressing issue in the Pakistan and has become infamously prevalent practice in the overall country. Electric power theft takes place in a variety of forms and thrives with the support of people from different walks of life: utility staff, consumers, labor union leaders, political leaders, bureaucrats, and high-level utility officials. It is a silent crime if any person avoiding legal right abstracts or diverts electricity [1]. Nonetheless, there are still consumers who commit it. This results that, the government provides power companies heavy subsidy to

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minimize the losses [2-3]. Literally, every stage of Electric power system is susceptible to theft. If we glance at past exertions for the prevention of electricity theft, the major part of work is realized on the User stage, while very minor work is done on Transmission and Distribution stages. To detect the electricity theft, sensor nodes are placed along the transmission paths on Transmission stage [4]. On Distribution stage to cope with this problem, a novel protection circuit based on current transformers [5] and an operation principle based on the introduction of harmonics into distribution system are designed [6]. Moreover, a theft monitoring system [7], SVMs (Support Vector Machines) method [8], correlation technique [9], novel technique based on high-frequency coupling windings [10], supervised pattern recognition techniques [11], and smart metering technology [12] are employed on the User stage.

2. THE APPROACH

We propose a solution that covers entire transmission to user stage and without synchronization among all of these the complete solution can not be achieved [13]. The block diagram of the proposed solution is shown in Fig. 1, and comprises of three stages:

- ◆ Transmission stage
- ◆ Distribution stage
- ◆ User stage

On transmission stage we propose a Wave conversion system based on PWM (Pulse Width Modulation) technique. The electrical power transmitted by city substation is stepped down by the transformer and strengthened by signal conditioning circuit. Then the conditioned electrical signal is converted into square wave signal by PWM technique, and after re-strengthened it is stepped up into actual voltage level by the transformer. On Distribution stage, the power is stepped down by distribution transformer and then supplied to consumers in single/three phase connection system. We propose the installation of adjustable rating circuit breaker on the connection of every consumer. By doing so, no any consumer would be able to use load beyond the provided limit. If attempted the circuit breaker would trip and the respective consumer would be disconnected from the electrical supply system. On User stage, where the electricity is delivered by the conventional electrical

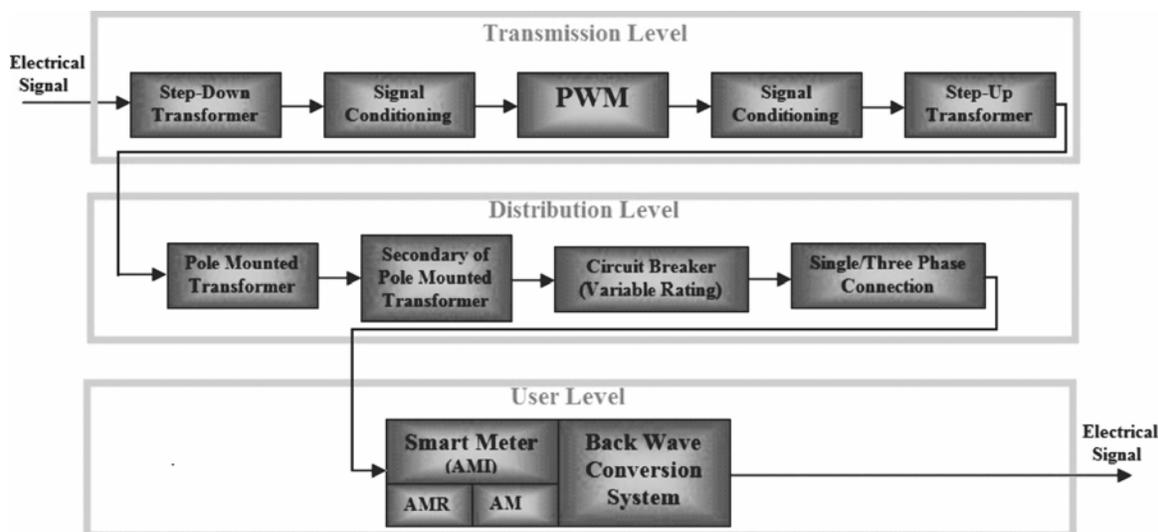


FIG. 1. BLOCK DIAGRAM OF PROPOSED SOLUTION

meters, we propose the installation of incredibly efficient technology "Smart Meters", possessing number of features along with two-way communication system and Back-wave conversion system producing actual electrical signal.

3. SOLUTION ON TRANSMISSION STAGE

Electric power from the power station is transmitted to load centers by transmission lines and distributed through distribution system by feeders, those run along the important road sides of the city. On this stage of transmission, we propose a Wave conversion system that converts incoming electrical sinusoidal signal into square wave signal. Consequently, the theft of Electric power can not be committed by consumers with bulk load requirement, factories, and industries due to incompatibility between the signal shape and electric-operatable systems [14].

3.1 Pulse Width Modulation

PWM converts a sinusoidal or time-varying signal into a sequence of pulses having a constant frequency and

amplitude, but the width of each pulse is proportional to the amplitude of that time varying signal [15]. The Fig. 2 shows the simulation circuit on Transmission stage based on an op-amp (operational amplifier) voltage comparator acting as a square wave generator. It has two inputs, DC reference voltage ' V_R ', sinusoidal input voltage ' V_S ', and one output square wave or PWM signal ' V_O '. The output pulse width of the comparator is determined by the values of R_2 , C_2 , and non-inverting terminal (+) of op-amp. The comparator is designed by using uA 741 op-amp. At non-inverting terminal (+) input that is pin (3) of op-amp, the reference voltage ' V_R ' is determined by the resistor values of R_1 and V_{R1} .

The charging and discharging path is provided by the combination of R_2 and C_2 . By adjusting the V_{R1} value, we can change the DC reference value ' V_R ' at non-inverting terminal (+) input when no input signal is applied. If the DC level of V_{R1} is fixed and an amplitude-varying signal is applied to the input terminal, the amplitude-varying input signal ' V_S ' is added to the fixed DC level and the reference voltage will be changed with the change in the amplitude of the amplitude-varying input signal ' V_S '.

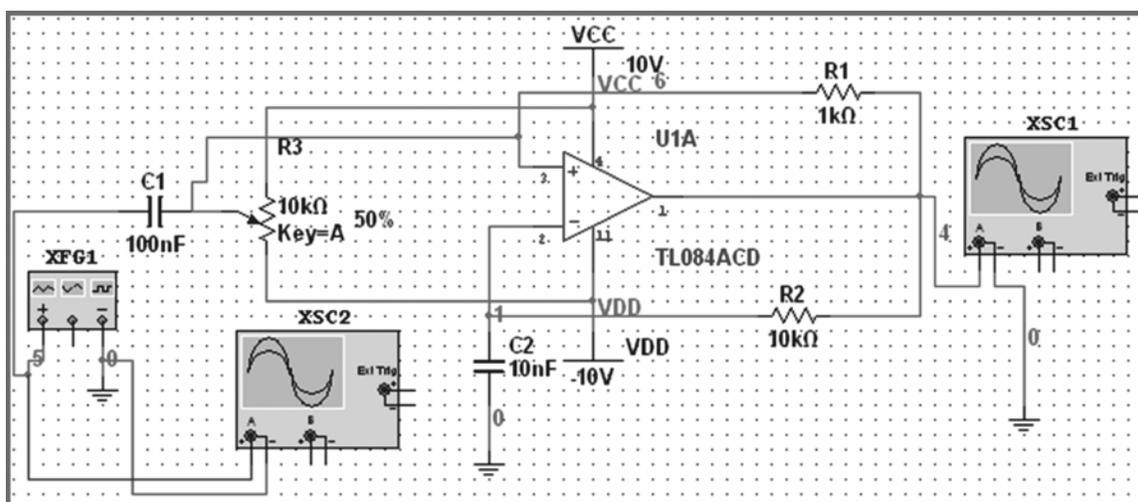


FIG. 2. SIMULATION CIRCUIT ON TRANSMISSION STAGE

3.2 Simulation Results

By keeping the ' V_r ' at a fixed level, the amplitude varying ' V_s ' is applied to the non-inverting terminal (+) of the PWM circuit with constant frequency of 60 Hz as shown in Fig. 3. At the output terminal the square wave signal is obtained, with the width proportional to the amplitude of ' V_s '. The ' V_s ' is applied with the voltage levels of 5, 10, and 15 Vp-pk and the equivalent PWM signals are obtained at the output terminal. Analyzing results, as shown if Figs. 4-6 we observe that the width of the square wave signal ' V_o ' is varying in accordance with the amplitude of ' V_s ' thereby resulting forming PWM signal.

4. SOLUTION ON DISTRIBUTION STAGE

The lines carrying PWM signal is transmitted to the pole-mounted substation and stepped down by distribution

transformer into utilization voltage. At the secondary of the distribution transformer each consumer is supplied Electric power using 3-phase 4-wire system and distributed according to single-phase and three-phase connections. We propose the installation of an adjustable rating circuit breaker on every consumer's connection with rating that would be set with respect to load requirement of consumer. So as consumer exceeds the load limit, the circuit breaker would trip and break the link of electricity [16-17]. The prototype simulation circuit on Distribution stage is shown in Fig. 7. To illustrate the action of circuit breaker, we have used fuse with different ratings. Four users with different load requirement are connected to the transformer and equipped with the related fuse rating.

4.1 Simulation Results

As the link of electric supply is established in circuit, we observe that among four consumers two are disconnected

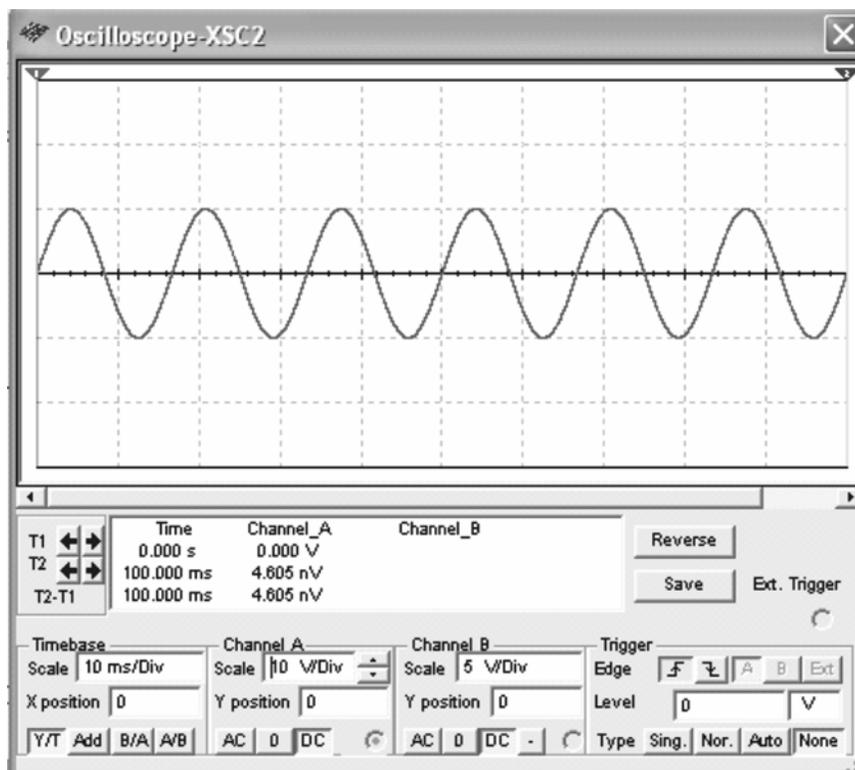


FIG. 3. ELECTRICAL SINUSOIDAL INPUT SIGNAL

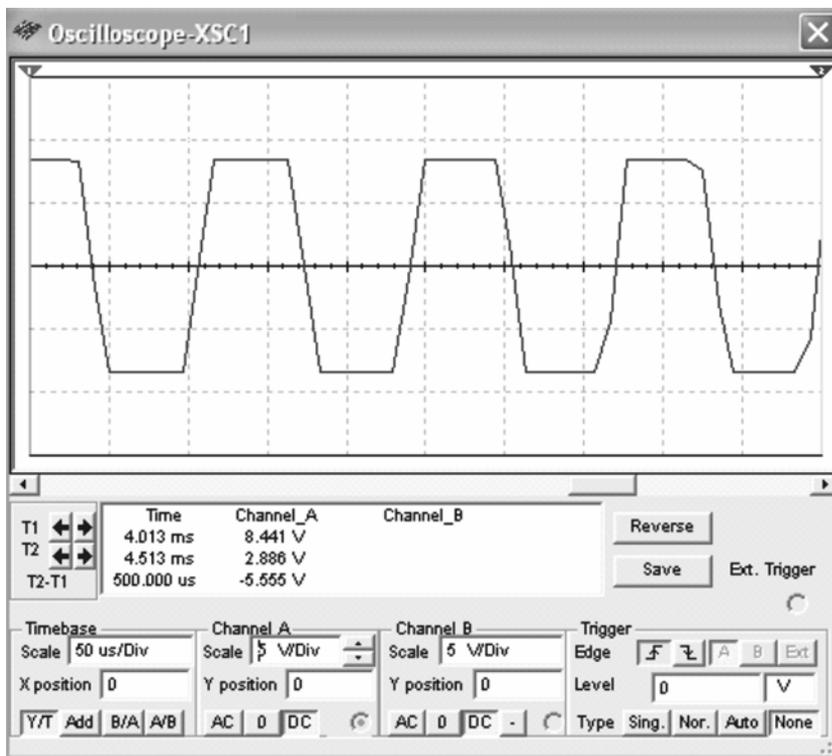


FIG. 4. PWM SIGNAL WHEN $V_S=5V_{p-pk}$

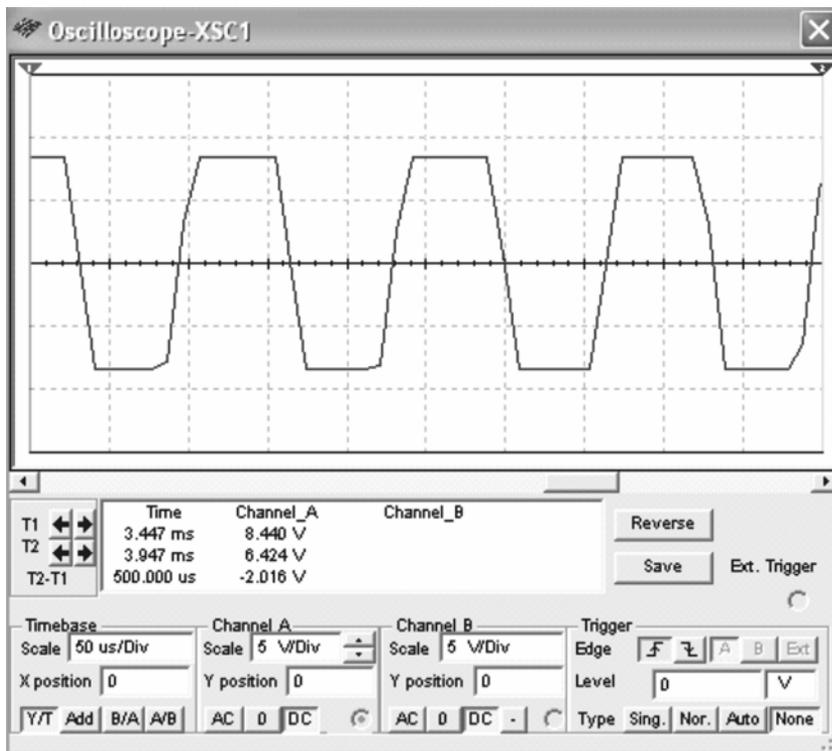


FIG. 5. PWM SIGNAL WHEN $V_S=10V_{p-pk}$

from electric supply due to the load used beyond the set limit as shown in Fig. 8.

The fuses of the users set on load requirement of 0.1 and 0.8A are blown and have no link of electric supply due to

load limit exceeded to 1A and 2A respectively. The practicable layout on the Distribution stage is shown in Fig. 9, the secondary of the transformer provides electricity in single/three phase connection to consumers. The circuit breaker is installed on every connection, it would trip and

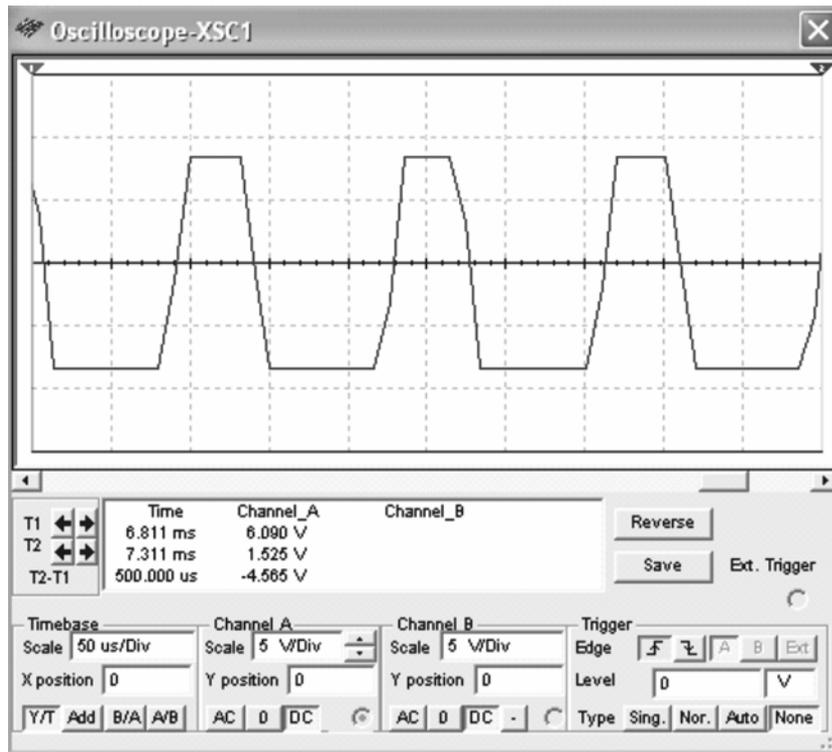


FIG. 6. PWM SIGNAL WHEN $V_S=15V_{P-PK}$

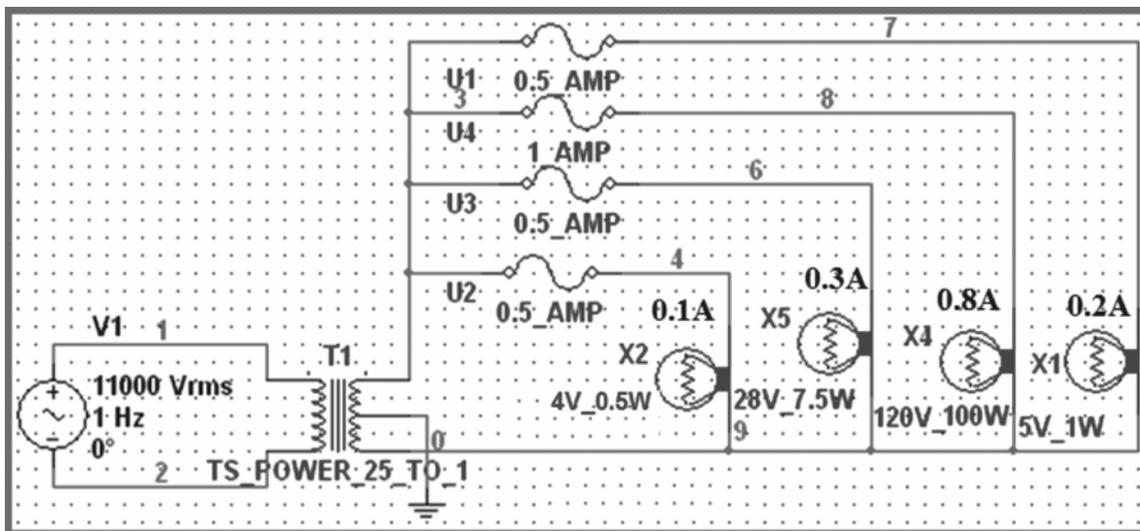


FIG. 7. SIMULATION CIRCUIT ON DISTRIBUTION STAGE

break link of electricity as consumer exceeds load beyond the provided. The consumer can be re-connected to electrical supply system by calling utility company, which will re-establish the link of electricity by resetting circuit breaker sited in password protected box.

5. SOLUTION ON USER STAGE

The electricity is delivered to consumer after distribution system by conventional electric meters. On this stage, we propose the replacement of these meters with smart metering technology integrated with Back wave

conversion system that produces actual electrical sinusoidal signal that is compatible with electrical appliances.

5.1 Smart Metering Technology

In recent years Smart metering technology has attracted concentration around the globe [18]. A number of countries have started deploying it while many others have set targets [19-20]. Very dramatic feature "two-way communication" can be provided by Smart meters between the Electric power supplier and the consumer [21]. Today

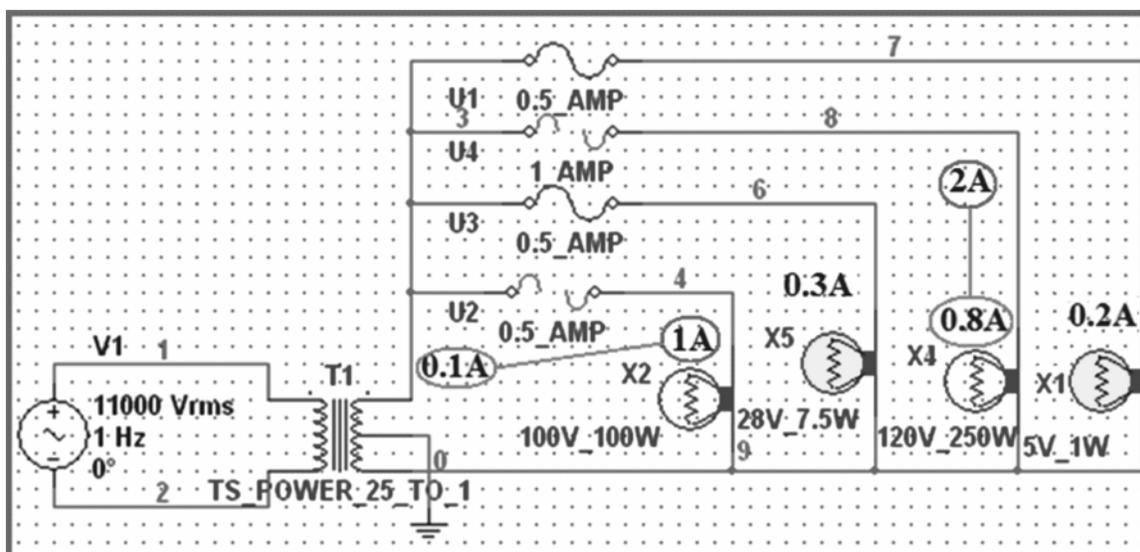


FIG. 8. SIMULATION RESULT OF CIRCUIT ON DISTRIBUTION STAGE

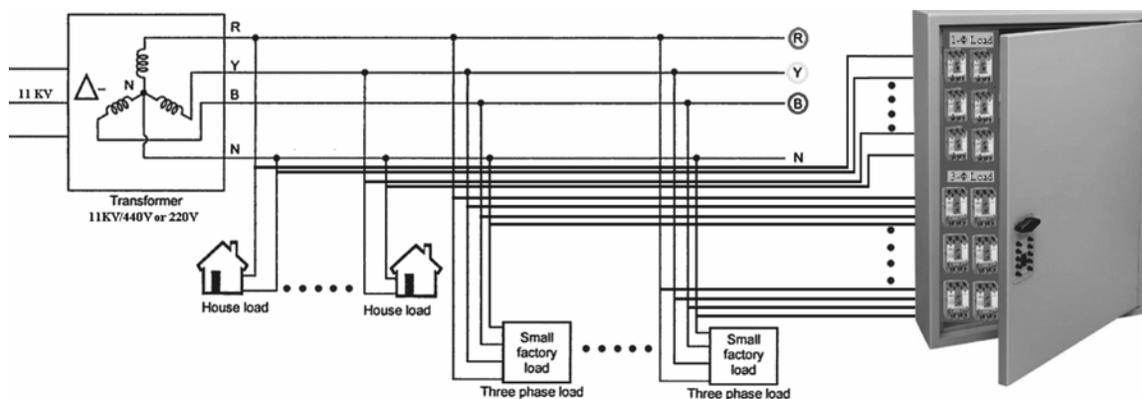


FIG. 9. THE PRACTICABLE LAYOUT ON THE DISTRIBUTION STAGE

the only information a consumer receives regularly is by a bill that may get there months after they have consumed the electrical energy, even then it may be a guesstimate [22]. The Smart metering provides:

- ◆ Real-time information about energy use.
- ◆ Enabling them to monitor and manage their consumption.

Smart meters are ingredient of AMI (Advanced Metering Infrastructure) [23, 24]. Via this infrastructure, the meter is connected to the Electric power supplier, other market actors and can potentially be coupled to appliances in the home via HAN (Home Area Network) [25]. Fig. 10 shows that how various communication networks connect part of AMI together. The AMI can be categorized by two ways that are differentiated by their levels of communication:

- ◆ AMR (Automated Meter Reading).
- ◆ AMM (Automated Metering Management).

5.2 Back Wave Conversion System

Back wave conversion system produces actual electrical sinusoidal signal, the simulation circuit on User stage is shown in Fig. 11. It comprises of two networks or circuits.

- ◆ Integration amplifier "Integrator".
- ◆ Wave shaping network "Diode function generator".

The first network "Integrator" is based on op-amp produces integration of the input PWM signal. The second network "Diode function generator" is a wave shaping circuit that produces sinusoidal signal with the combination of diodes and resistors [26].

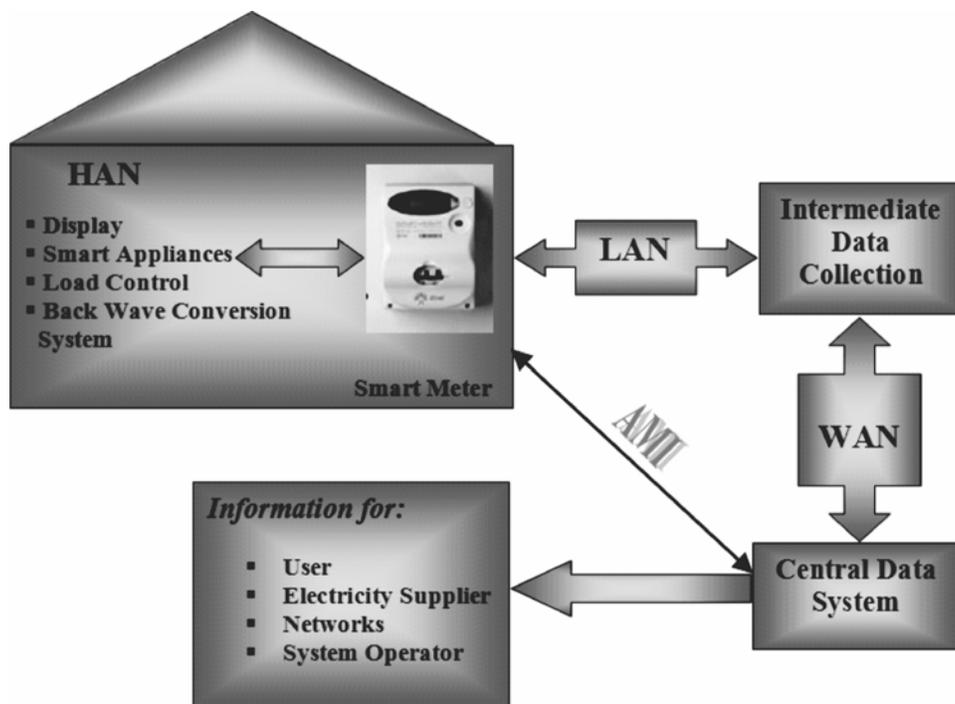


FIG. 10. GENERAL LAYOUT OF AMI

5.3 Simulation Result

The $+V_{CC}$ and $-V_{DD}$ are set at +12V and -12V respectively. The incoming square wave signal with 10V p-pk and 50%

duty cycle as shown in Fig. 12 is applied to the inverting terminal of the first network. The corresponding sinusoidal signal is produced at the output terminal of second network as shown in Fig. 13.

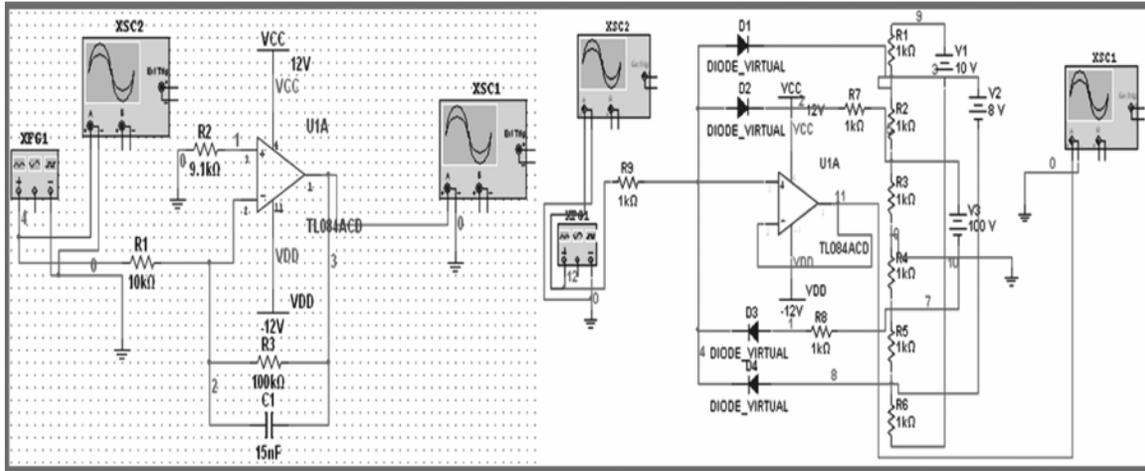


FIG. 11. SIMULATION CIRCUIT ON USER STAGE

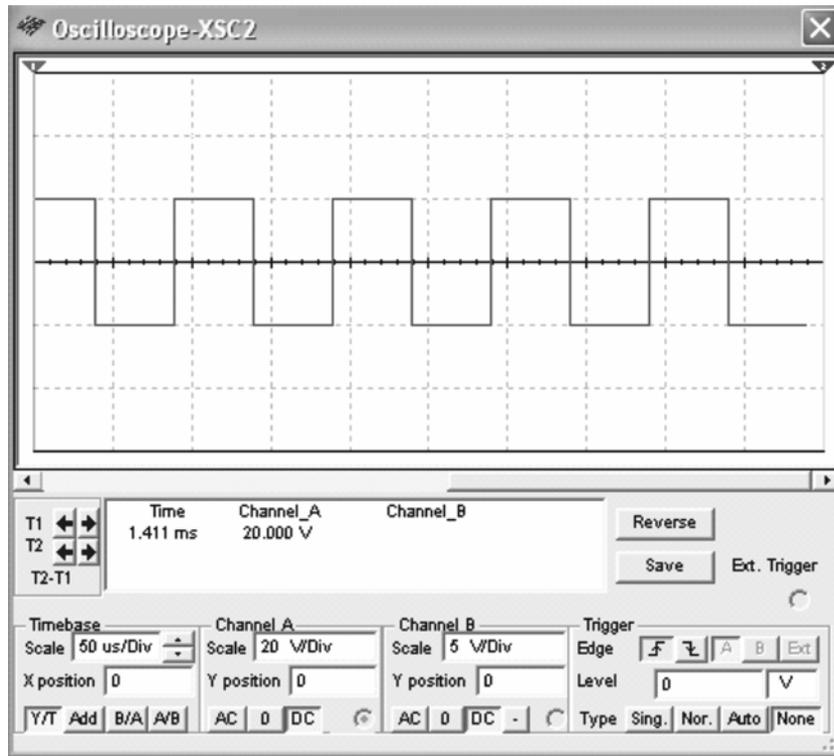


FIG. 12. SQUARE WAVE INPUT SIGNAL

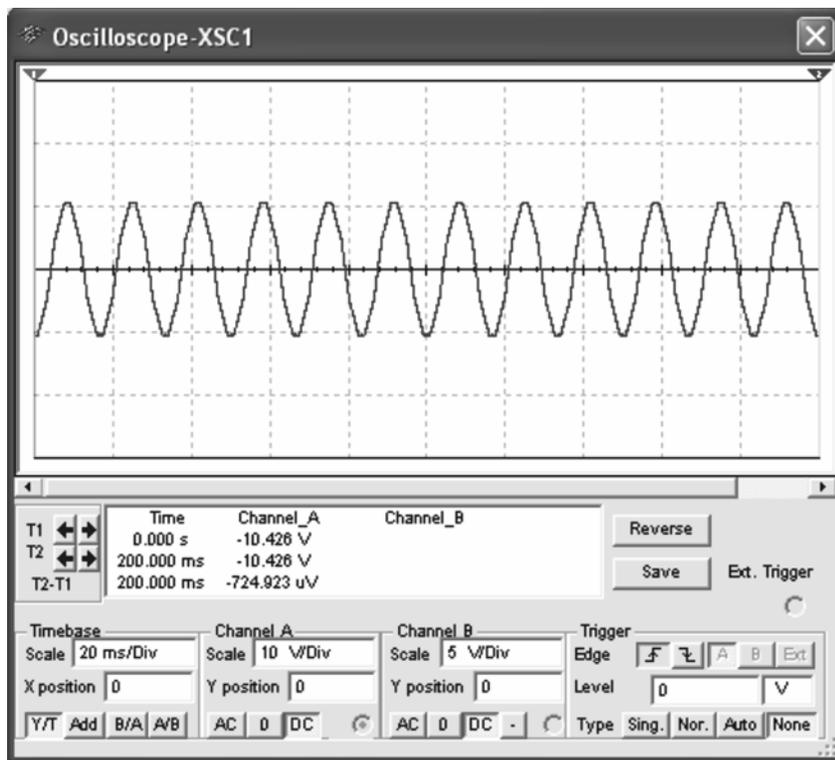


FIG. 13. ELECTRICAL SINUSOIDAL OUTPUT SIGNAL

6. CONCLUSION

Electric Power Sector in Pakistan is suffering from record level Line Losses. In our Research, we have proposed Electric Power theft Solution based on three levels that is practicable as well as applicable. The Proposed Solution has been simulated on National Instruments Circuit Design Suite Multisim v.10.0 with faithful results. At Transmission stage the required PWM Signal is obtained by op-amp design application, and the width is proportional to the amplitude of any one of the inputs i.e. DC Reference Voltage and Amplitude Varying Sinusoidal Signal. At Distribution stage as the consumer who steals Electricity exceeds the load limit provided by Utility Company, the Fuse gets blown out and the respective consumer is disconnected from Electrical Power. On User stage the PWM signal is obtained back into Electrical operating

signal by Back Wave Conversion System so that consumer may operate appliances safely. If the existing Electric Power System is devised with the proposed solution, due to saving from power theft, the dependence on huge future investment on alternate energy solution may be avoided. In a nutshell, by taking this approach Pakistan may be able to get rid-off from Electricity shortage.

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