Smart Grid With ADSL Connection For Solving Peak Blackouts In West Bank

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Abstract—*This paper introduces a proposal for solving the problem of frequent power cut-off and blackouts; mainly in summer, due to peak-limit exceeding in the West Bank. The idea is based on developing a smart grid that uses the wide spread ADSL Internet as a communication tool. An embedded control unit (ECU) is used for data collection of power consumption, communication and control of end user loads. In addition to its ability to convert regular prepaid digital meters into smart meters, it has the ability to perform different scenarios of demand side management for reducing total consumption at peak hours, and hence preventing the harsh penalty of total blackout for the local power distributer*

Keywords-component; **smart grid, ADSL internet, Demand side management.**

I. INTRODUCTION

For any power distributer, smart grid is considered as an advanced solution for many problems especially for those related to demand side management. However, the lack of communication network for the electric grid makes it very difficult to establish a smart grid or even to think about using modern equipment such as smart meters. For the case of the West Bank, it is very difficult at this time to install a communication network for different reasons such as financial and political obstacles.

Most of electric power consumed in the West Bank and Gaza is purchased from Israel. The electricity system in the West Bank consists of numerous isolated distribution systems owned and operated by municipalities and village councils, and it has no significant generation or transmission capacity. Each municipality or council has singed a Purchase Agreement with the Israeli Electric Company (IEC) to regulate supply conditions of power to that local grid. In addition to technical requirements, these agreements include:

1- Flat rate tariff of electricity which is much higher than in Israel
2- The upper Limit for Peak demand of electricity for the city or village
3- Penalties for Power factor violations

As Palestinian customers are considered of least priority for IEC, and according to the purchase agreements, IEC shuts down power supply to any Palestinian city or village if demand exceeds the specified peak limit specified to the distributor. This resulted in a large number of hours of blackouts in many cities and villages in the West Bank at peak days, mainly in summers in the last decade. For example, in summer of 2008, Tulkarm city had more than 300 hours of blackouts mainly at noon times. The city municipality was forced to pay hundreds of thousands of dollars to purchase extra capacity from IEC. With the exponential increase in number of installed air conditioning units (A/C units), the new specified peak is expected to be exceeded this year and following years.

This paper proposes a solution for this problem for Palestinian customers using smart grid technology. While it is very difficult to install a special communication network for the smart grid, we propose to use the wide spread ADSL internet as a communication tool for this purpose. According to Patel (the Palestinian telecommunication company) there are more than 96,000 residential and commercial ADSL customers in the West Bank. Also, according to our survey, most of those customers have installed air conditioning units at their offices or homes where ADSL is available. In addition to that, around 67% of power customers are using prepaid digital power meters.

II. THE PROPOSED SYSTEM

The proposed smart system has the following components:

1- Central computer (server of power distributor) which is used to monitor continuously the total demand of power distributor, to communicate with remote load units and to carry out the energy management software applications. This is connected to the main digital meter from one side and to the ADSL internet from the other side.
2- ADSL internet, which is the backbone communication tool for this system. ADSL is wide spread in the West Bank with more than 96,000 subscribers in the residential and commercial sectors.
3- Embedded Control Unit (ECU) which is installed at the end user side. This locally designed unit is connected to the digital meter, the Internet modem and to the A/C unit to be controlled.

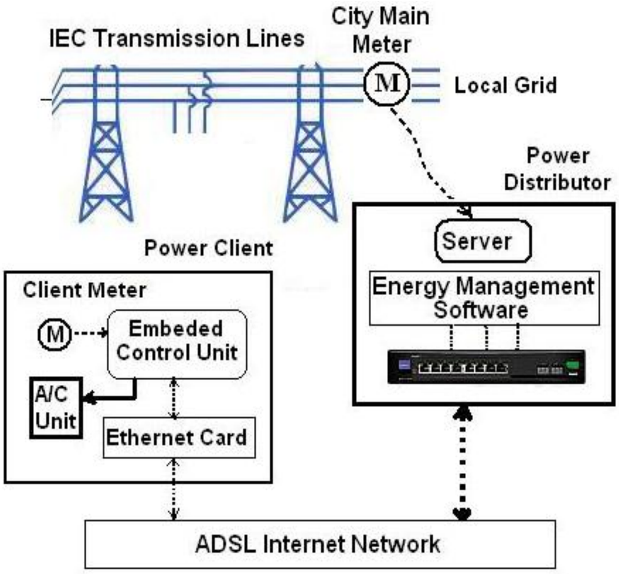

Fig. 1. Simplified scheme of the proposed system

Fig. 1 illustrates the scheme of the proposed system. The needed number of customers to be connected to this system will be decided according to maximum power to be shed. If the customers are grouped into ten groups, then each group will include N customers according to following equation:

$$N = \frac{\text{Maximum Load to be shed (KW)}}{(\text{Average consumption of (A/C's) of customer (KW)}) * 10} \qquad \ldots\ldots(1)$$

In such case, the customers with large A/C units and connected to the Internet will be selected. According to our survey, almost all of the investigated customers have no objections for this proposal. They think that they prefer few minutes per hour without air conditioning over complete blackouts for few hours.

III. Communication System

The system consists of a centralized server and a set of remote and distributed objects (clients) that communicate directly to each other via Internet. The middleware provides a uniform, generic and fully specified application protocol. TCP/IP protocol has been selected for its wide applications and simplicity for transmitting data and control codes. The main server which is owned by the power distributor has a fixed IP address which will be used by all remote units for sending data to the server or to receive control codes from it.

At the client side, the Embedded Control Unit (ECU) is linked to the digital meter via an interface. A built-in Ethernet network interface is used to connect the ECU to the internet modem of the client. Triacs or relays are used to control customers loads (in this case the Air Conditioning units). The server of the power distributor sends a request signal to each ECU when consumption level is reaching a critical level close to specified peak limit of the distributer. To guarantee continuity of communication, each remote unit addresses the central server several times a day, and makes registration that includes a username and a password. This is essential to ensure that remote units are ready for data communication and to provide their IP addresses the many not be fixed and may change frequently.

IV. The Embeded Control Unit

Fig. 2 shows the developed control unit to be used at the client side and will be embedded in the metering unit of the customer. This unit; which has been developed, programmed and built locally, consists of the following major parts:

- Embedded Ethernet network interface. It includes an implementation of TCP/IP protocol.
- 8-bit microcontroller
- Triacs or relays for power control switching.

Microcontroller software can perform these major functions:

1. Establishing secure communication with main server via the ADSL internet.
2. Reading power consumption directly from the prepaid digital meter on hourly bases.
3. Transmitting coded data to main server via internet using TCP/IP protocol.
4. Receiving control codes from the main server.
5. Performing control of A/C units in response to control codes, according to demand side management scenarios performed by main server.

Embedding this unit to the regular digital meter of the customer will convert it into a smart meter with control capabilities.

V. System Operation

The system has been tested for data communication which proved its validity. Demand side management was simulated using old real data for loads of previous years. The following explains data preparation and operation of the proposed system.

1. Daily Load Curves

The possible application of the proposed system for solving Peak blackouts was studied and simulated for the special case of Tulkarm city. The data for hourly consumption have been

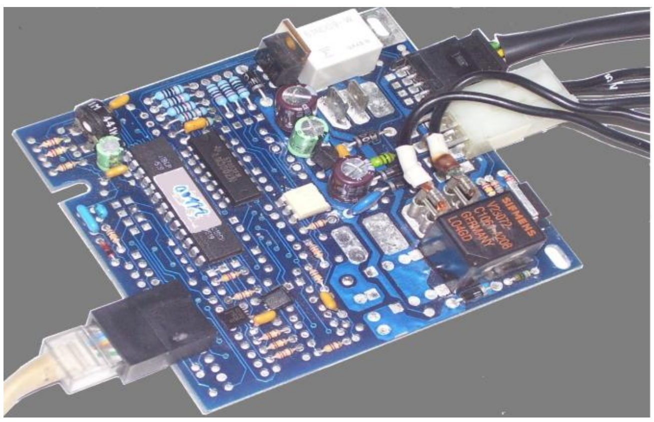

Fig.2. Embedded Control Unit

Fig. 3. ECU installation at the meter side

collected from different sources including Municipality of Tulkarm; the electric distributor, Palestinian Energy Authority and research studies. Fig. 4, shows a typical load curve for the city in a typical day in winter. Note that the peak demand of the city in winter is far below the Peak Limit as specified by IEC. It is very rare that this limit is exceeded as Tulkarm area is relatively warm in winter. Fig. 5 shows a sample of the load curve in a hot day in summer. It is clear that the Peak Limit restriction has been violated between 10:00 am and 2:00 pm. In most cases this will result in a harsh penalty by IEC by cutting off power supply to the city for many hours as estimated by IEC. It is our estimation that the load may exceed the peak limit by less than 3 MW only, but this is a justified reason for

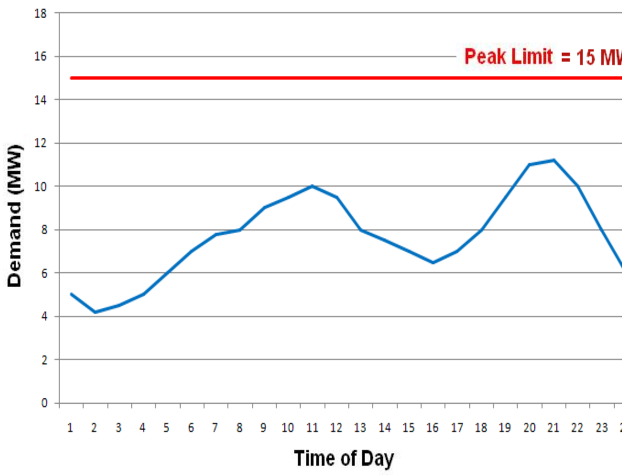

Fig. 4. Load curve for Tulkarm in Winter

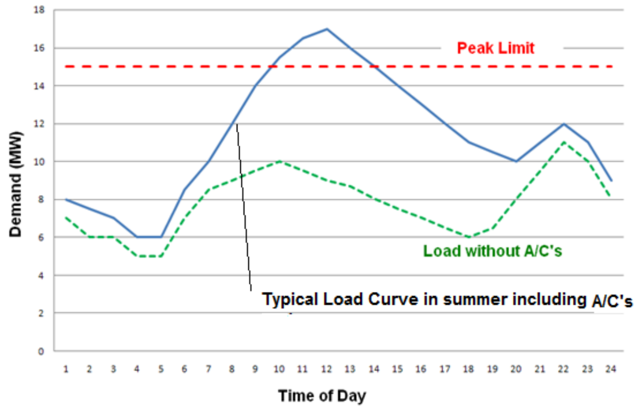

Fig. 5. Load curve for Tulkarm in Summer

IEC; which suffers power shortage in summer, to cut off power for local Palestinian power distributors.

In order to estimate the daily load curve in summer without including Air Conditioning consumption, the following method was used:

1. By selecting 20 residential and commercial customers and comparing their power consumption at different times with air conditioning units turned (On and Off).
2. The hourly demands for those units were estimated by multiplying the total load capacity of all A/C units connected to one substation with the hourly Load Factors for monitored air conditioning units (two units in this case) at the same time in the same area.

From fig. 6, and according to equation (1) the total number of customers may not exceed 2000. This is due to the fact that the load to be shed is always less than 3 MW, which is much less than the estimated load of air conditioners in the city. Average load of A/C units per customer was estimated at 1.5 KW.

From the curve, it is clear that power consumption of air conditioning units increases total demand by more than 50% at noon hours, which is the main reason for exceeding the peak limit and the cause for power blackouts at hot days. It is important to note that most of electric power in consumed in the residential and commercial sectors at day time.

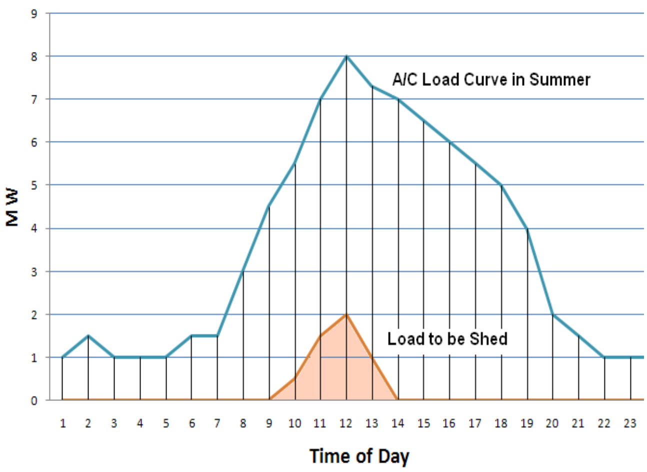

Fig. 6. Load curve of A/C units in a hot summer day in Tulkarm

2. Demand Side Management

In order to avoid blackouts, it is necessary to reduce total consumption of power distributor to be below the peak limit. This can be achieved by forcing some of those A/C units to turn off for limited periods of time. This procedure will be circulated among the groups of customers for the expected period of peak violation. With continuous monitoring of total consumption of the power distributor, the Energy Management software will be able to estimate the number of units to be turned off and the period for that. All of this will be done by the main server of the power distributor.

The need for short term load forecasting is not important. All decisions can be made instantaneously based on real data collected from main meter of the distributor. The energy management will be activated whenever the total demand is approaching the specified peak limit. Also, the impact of demand side management on total demand can be seen immediately. Increasing or decreasing the number of controlled units and the periods of time is decided according to this impact.

3. Impact of DSM on Load Curve

Based on summer load curve for Tulkarm city, load shed for a period ranges between 5 and 10 minutes were simulated according to the following procedure:

- DSM will be activated when load demand exceeds 14.5 MW.
- Customers are grouped into 10 groups according to their number (using last digit of unit number from 0 to 9). Each group consists of around 200 customers with total A/C load around 300 KW.
- Load shed will be circulated among all groups for 6 minutes period for each group (10% of all customers).
- When measured load is higher than 14.75MW, the number of controlled groups will be increased by one. In other words; another 10% of the customers will be included to controlled groups.
- When the measured load goes below 14.5, number of controlled groups will be reduced by one.
- When number of controlled groups becomes zero, then DSM is completed and stopped.

The impact of this procedure on load curve is illustrated in Fig. 7.

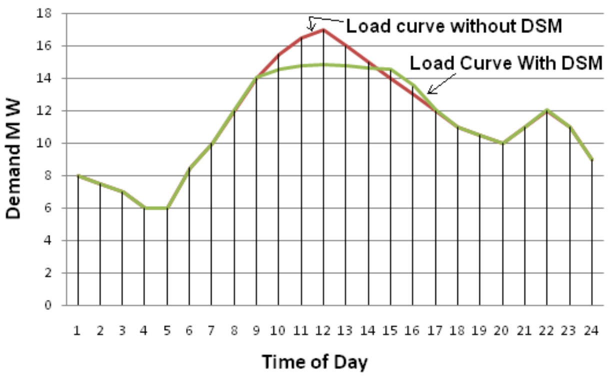

Fig. 7. Impact of demand side management on load curve.

V. Reliability and Security

The communicating devices in the system rely on the communication backbone in their respective domains to send and receive data and control codes to maintain system stability. The ADSL internet reliability is affected by a number of possible failures. These failures include time-out failures, network failures, and resource failures. The ECU repeats data sending if there is no acknowledgment signal is received from main server for more than 30 seconds. To prevent long term shut off of A/C units, the ECU turns the controlled A/C unit ON automatically after 10 minutes if data communication with server is halted for any reason.

Security of information is guaranteed by data coding and log-in procedure for each remote unit. In this case, security level has been improved by authorized access to the real time data and control functions, and use of encryption algorithms to prevent spoofing.

VI. Conclusions

The proposed system presented in this paper can convert any power grid into a smart grid using regular ADSL internet as a communication tool. Also, the embedded control unit with an interface can convert a regular digital meter into a smart meter which is capable of sending metering data to the server of the main supplier. Demand Side Management can be implemented in this system using control capabilities of the control unit. Reliability of system depends mainly on reliability of the Internet in the specific area of the grid. Finally, simulation results show that this system can solve the power blackouts at Peak Hours through the implementation of demand side management scenarios designed for this purpose.

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