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A systematic approach towards developing prototype of AMI based DSM model for load management

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Participating in demand response has significant advantages for both consumers and electricity producers, i.e., saving on high electricity prices for the user and helping utilities in peak load curtailment. Further increased the use of renewable energy and energy storage, along with the need to increase energy efficiency are the main driver for the implementation and utilization of DSM. In DSM to monitor and control of the low voltage power grid, a computer system (a combination of hardware and software) is provided which is advance controlled by SCADA (Supervisory Control and Data Acquisition) System. Next generation application and DSM concept are important with smart grid to give the answer to the need of the changing power system. This research paper insights the development of advanced metering infrastructure based demand side management model for load Management. The main objective of this application is consumption optimization and automation in operation. This paper proposes a fixed load control strategy with fixed forecasted photo voltaic generation, battery storage system and priority based load curtailment mechanism.

Keywords: *Demand Side Management (DSM), Advanced Metering Infrastructure (AMI), Smart grid, Energy Management System (EMS)., smart metering, dynamic pricing, Transmission and Distribution losses (T&D), Field Programming Gate Array (FPGA)*

1.0 INTRODUCTION

India is the fourth largest energy consumer in the world after the United States, China, and Russia. In recent years, India's energy consumption has been increasing at a relatively fast rate due to population growth and economic development. Rapid urbanization and improving standard of living of millions of India's households, the demand is growing significantly, The India's energy planning, which is based on the twin objectives of high economic growth and providing electricity to all. According to Central Electricity Authority (CEA), Ministry of Power, Government of India (refer Table-1) (i) The per capita energy consumption in India is 917.8 kWh (2013-2014), while the average energy consumption in the world is 2892 kWh per annul (ii) Present options of thermal, hydro and nuclear generation are not sufficient to meet widen demand-supply gap. The only option is renewable energy. (iii) The transmission and distribution (T&D) losses are 23% highest - among developing country, The Energy Research Institute (TERI) reported a 50% (Uttar Pradesh and Bihar States of India).

The commercial losses, mainly occurred due to pilferage and theft of energy, hooking

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and tapping from the bare conductor of LT consumers, unauthorized extension of loads, bypassing of meters, meter error, etc. The reasons for technical losses are improper energy management, inadequate kVAR compensation, poor power quality of rural pumps and cooler / air conditioners and industrial loads.

The smart energy management and automation is the true solution to deal with a power sector problem. It will not only help to solve the problems of aging distribution infrastructure, the burden on transformer and feeders but also ensures a generalized intelligent energy system to improve system reliability, reduce T and D losses, smart metering. Bidirectional communication capability for remote control and customer has up to date information on energy consumption and price.

All such issues can be resolved using the new technology of smart grid, adding for measuring, monitoring, communication, analysis and control. The capability to bring high efficiency and optimal electricity sector by integrating IT technology onto power network. The algorithm for DSM and its overall architecture for home DSM to achieve cost saving and peak shaving.

2.0 LOAD CONTROL STRATEGIES

The purpose of load management techniques is to reduce peak demand to level daily, seasonal or annual electricity demand. The most widely applied load management strategies are peak clipping, valley filling and load shifting [1-23]. Figure 1 shows load leveling methods for modification in load curve.

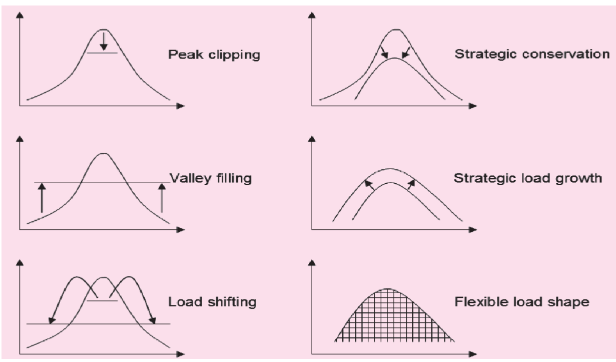

FIG. 1 LOAD CONTROL STRATEGIES

3.0 CONFIGURATION OF ADVANCED METERING SYSTEM FOR DSM MODEL

The configuration of Advanced Metering Infrastructure (AMI) is shown in Figure 2. It mainly consists of smart energy meters, meter communication module, data concentrator unit and data collection and management center connected to local area and wide area network. A smart meter is usually an electrical meter that records the consumption of electrical energy in intervals of an hour or less and communicates that information in daily to the utility for monitoring and billing. It also provides two way communications between the utility and end user. This meter also records of previous consumption in its memory for lateral retrieval. In order to provide a communication between smart meters and utility, Broad Band over Power Lines (BPL), Power Line Communications (PLC), fiber optic communication, fixed radio communication (land line) are used. The communication protocols and communication technologies are Modbus, GSM/GPRS, RS232/RS485 and TCP/IP, Zigbee, etc. with data communication rate of 1Mbps or 2Mbps. The data concentrator unit will acquire data from meters and send it to the Meter Data Management Center (MDMC) through GPRS communication. The event date record is stored as voltage, current, active and reactive power, frequency. The network interface RS232 / RS 485, WAN uses 3G/GPRS modem connects data of distribution transformer to the central server.

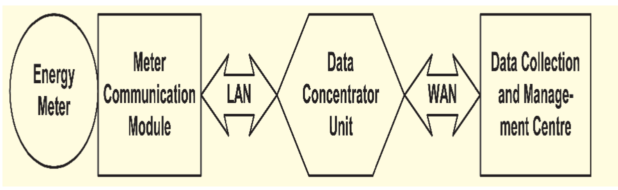

FIG. 2 CONFIGURATION OF ADVANCED METERING INFRASTRUCTURE

4.0 SINGLE LINE DIAGRAM

Figure 3 represents system uses CT and PT sensor to measure the consumed power. The analog value sensors are converted into digital and handled in the control unit by energy metering block. The load transfer switch transfers them to photo voltaic and utility. The curtailment of loads is done on the basis of priority set by consumers and curtailment will be done when peak demands occurs at utility end. The deviation of peak power with respect to average power, the load curtailment will be done, to ensure frequency within a specified the limits.

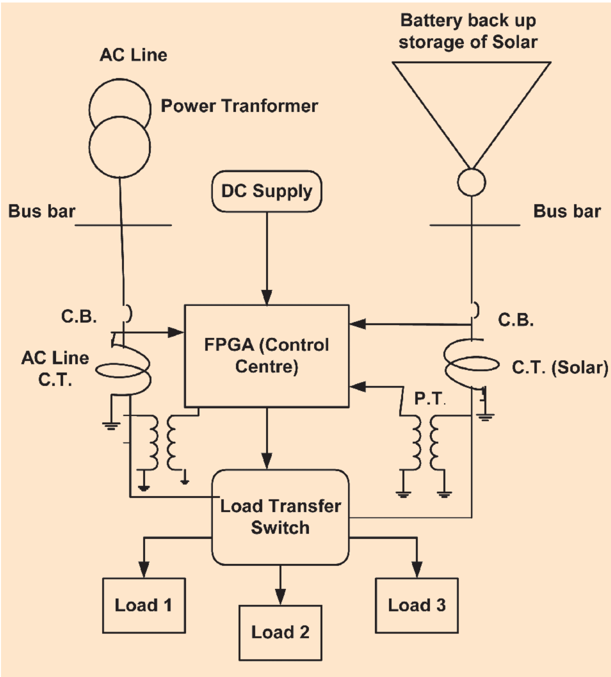

FIG. 3 SINGLE LINE DIAGRAM OF LOAD MANAGEMENT

5.0 SYSTEM TOPOLOGY

The system consists of a load transfer switch, A/D converter, Zigbee to send information, Current Sensor (CT), Voltage Sensor (PT), the control unit. FPGA kit is used for implementation of load control mechanism through HDL coding and design. The real time implementation is proposed through Lab VIEW™. FPGA generates control signals which are concurrent in nature and 500 kHz clock pulse is used for running of ADC. The smart energy meter will provide metering of voltage, current, real power of the battery and utility. The control unit will generate control signals which control the load transfer switch and signal to energy management center through universal asynchronous transmitter (UAT and Zigbee). The load management technique will be tested for normal and user based load control based on consumer priority for switching / transfer of load.

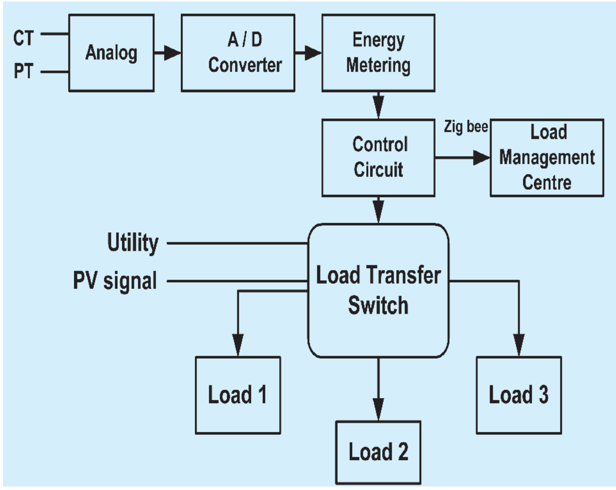

FIG. 4 SYSTEM TOPOLOGY FOR LOAD MANAGEMENT

6.0 ALGORITHM FOR LOAD

The basic idea for development of load control algorithms is based on the use of PV and utility source optimally at the time of peak load curtailment. The information about the utility and the condition of battery status of PV system and the current from current and potential transformer. Here the power consumption is checked and compared energy sources. These collected data by a sensor of PV systems and utility are transformed into specific factor (K) which is basically the difference of the available power of PV and expected power demand. The system chosen to use PV or utility source on the basis of following conditions.

K > Default Value: Use power from PV system

K = Default Value: Use power from both the sources (Utility source and PV source)

K < Default Value: Use power from utility source

According to the battery efficiency the default values are adjusted. It is noted that the frequency is limited within the range of rated ± tolerance. The rated frequency is taken as 50 Hz in India and frequency for use is taken as in tolerance limit of ±0.2 Hz (as per norms of regulatory).

For this fair frequency band the customer may get incentives. Percentage of load curtailment from utility depends on deviation of real power from peak to average power that the utility can supply to keep the frequency within fair band. The Target value of load curtailment lies within 10-20%.

The voltage profile and reactive power requirement will also be improved in a substantial amount and the power delivered at the time of applying DSM will be managed after load control mechanism. It affects overall cost and reduce CO_2 emission level.

7.0 PROPOSED METHODOLOGY

7.1 Digital meter with Communication module

Enables the capability of two-way communications-with the ability to measure the incoming and outgoing flow of electricity from a specific location. The meters will capture the information and transmit through the local area network and wide area network, during short intervals at prescheduled times.

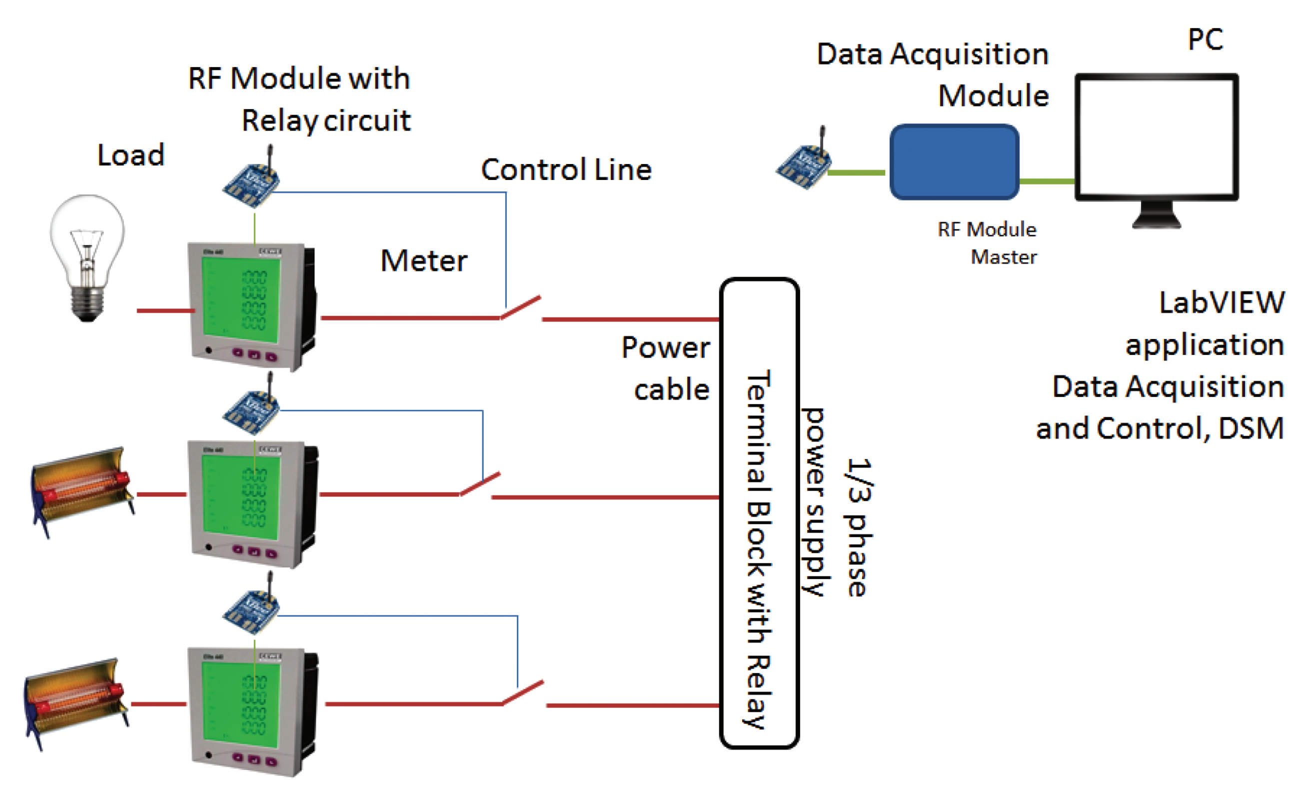

FIG. 5 PROTO TYPE EXPERIMENTAL SET UP FOR LOAD MANAGEMENT SCHEME

6.1 Metering Telecommunications

Consisting of two parts-the local area network and the wide area network connections. This communication infrastructure provides the physical devices required to enable two-way transmission of data between several meters and data center. There are several different ways this communication infrastructure can be implemented, depending on the metering system selected.

7.2 Automated Data Collection System

This software application is designed to aggregate meter usage and event data from smart meters and manage the communication infrastructure.

7.3 Demand Side Management

This software application is designed to manage the demand and supply, based upon the set of conditions.

8.0 DESIGN PARAMETERS OF DSM-AMI MODULE

RF Module with Relay

- 2.4 GHz or 865 MHz ISM band operations
- Mesh Networking, Point – to point, Star Networking topology
- Configurable on-air data rate of 250 kbps, 1 Mbps or 2 Mbps
- Relay 5 A, 220 V, operation voltage 5/12 V DC

Data Concentrator Unit

- Real Time Processor : 256 MHz
- Memory:28 MB Non-Volatile Storage and 64 MB DRAM
- Communication Protocol: ModBUS-Serial/ TCP (Master/Salve), DLMS, IEC

Network Interface:

- 10/100 Mb/s Ethernet port (One no.)
- RS232/RS 485 (Multiple ports optional.)

Low Power Coordinator:

- 2.4 GHz or 865 MHz ISM band operations

Energy Meter:

- Three / Single Phase
- Modbus/DLMS protocol

9.0 RESULTS

The load management technique will be tested for normal and user based load control based on consumer priority for switching / transfer of load. The graph of Figure 6 shows the performance of load management for normal, efficient load, demand limiting, demand shifting and demand shedding strategies.

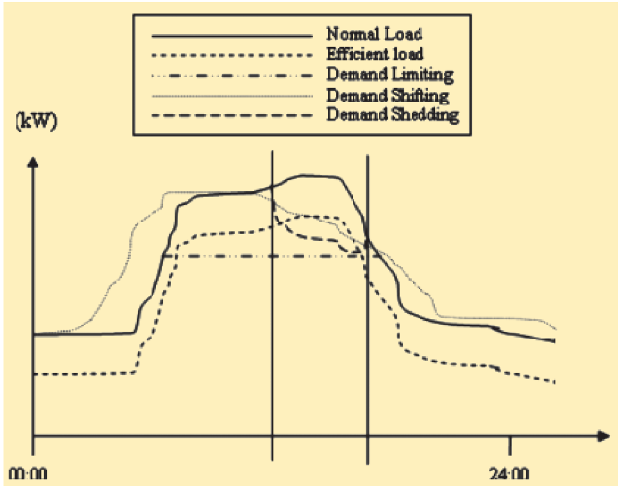

FIG. 6 GRAPH AFTER MODIFICATION IN LOAD CURVE

10.0 CONCLUSIONS

The load control / management are designed for improvement of energy efficiency of PV system and utility. The proposed system is cost effective and gives incentives to user from participation in DR programme. The user can easily monitor and manage their electricity load according to the requirement of EMC. The information of daily consumption of electricity will be stored in a file. The user can easily view their energy consumption. Overall cost after applying DSM at the time of peak load for daily and monthly load will be reduced considerably.

The proposed design of a proto type of AMI based DSM model will manage load and improve the efficiency of PV and utility. The system simulation will be done on Lab VIEW™.

11.0 TECHNO – ECONOMICAL – ENVIRONMENTAL BENEFITS

- Reduce peak load in electricity by consumer flexibility, i.e. by increasing the demand side response.
- New Automated metering technologies enable 'visibility' of electricity use.
- Modern metering and communication system enables utilities to perform direct load control measures and automated demand response.

- Load control strategies at demand side could influence the environmental performance of an energy system, decreasing emission
- Tariff of the consumers would be significantly reduced if they improve the consumption pattern.
- Contribute to be an increased sustainable and more effective energy sector.

TABLE 1			
INDIA'S INSTALLED CAPACITY (AUGUST 2014) TOTAL = 253,390 MW SOURCE: CEA			
Coal 152,310 MW (69.06%)	**Hydro 40,799 MW 16.33%**	**Nuclear 1.52%**	**Renewable 31692 MW 12.7%**
1	Required capacity addition	90,000 MW	
2	Capacity require-ments of India by 2030	685 GW	
3	Renewable energy potential	245, 880 MW (2012-2017)	
4	Energy deficit	8.5% (Average)	

TABLE 2		
SMART GRID ROAD MAP PLAN - 2013		
During 12th Plan	**During 13th Plan**	**During 14th Plan**
Reduction of power cuts	Min 12 hour supplies for all	Stable and quality supply
AT &C Reduction below 15%	AT &C Reduction below 12%	AT &C Reduction below 10%
Enable prosumers	AMI Roll outs	Active participation of prosumers
Mandatory Demand Response	Mandatory demand response	Smart energy efficiency programs
Renewable energy integration of 30 GW	Renewable energy integration of 80 GW	Renewable energy integration of 130 GW

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