Theme: Foundational Blocks for Smart Grids

Demand-side flexibility as a demand response Mechanism – A review

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Introduction

- ✓ Global electricity demand reported an yearly increase of 6% and reached 24700 Terawatt hours (TWh) in 2021
- ✓ The share of electricity in total final energy consumption (TFEC) in 2021 stands at 20%.
  - *TFEC shall reach 22% in 2030 in a normal scenario*
  - *In the 'net zero emission' scenario (NZE), the share of electricity in TFEC is expected to reach 28% by 2030 and 52% in 2050*
- ✓ The load curve is constantly changing. Utilities worldwide are tirelessly working to meet supply and demand during peak hours.
  - *The daytime peak :- An upcoming challenge for utilities*
  - ***Huge increase in the** energy demand translates to capacity additions in the generation, transmission, and distribution*
- ✓ Grid Modernization:- Involves smart grid/digitalised grid, smart consumer, smart grid technologies, increased renewables etc.
  - Grid modernization demands heavy investment for the utilities worldwide

Introduction

- ✓ Utilizing the existing flexibility assets for demand response is becoming a policy priority with grid modernization.
- ✓ The increase in the use of distributed renewable sources, increased use of electric vehicles, and Gigawatt scale battery energy storage aid the demand flexibility
- ✓ Indian Scenario:- According to NITI Aayog 2019, 24% of the electricity consumption is from the residential sector and 28% from the agricultural sector
- ✓ Peak demand is about to double by 2030 in metro cities like Bengaluru, Hyderabad, Mumbai, and Kolkata according to ‘Alliance for energy efficient economy’
- ✓ Demand flexibility is a virtual source. It creates a flexible load bank with the help of its potential consumers
    - ***This source can manage peak load without increasing the electricity price, improve the grid reliability and stability and curtail emissions***

Importance Demand Flexibility

- ✓ Demand flexibility: Is a process in which a portion of the demand is curtailed, shifted, or increased in a particular period
  - ***According to IRENA, 'demand-side flexibility' is defined as a portion of the demand arising from the electrification of energy sectors, such as heat or transport via sector coupling, that could be reduced, increased, or shifted in a specific period***
  - ***Demand-side flexibility (DSF) is the ability of customers to change their consumption and generation patterns based on external signals***
- ✓ DF helps to reduce the peak load, shape the load curve by integrating variable renewables to match the load demand and shift the load from a period of high per unit price to a period of low per unit price
- ✓ The IEA report on demand flexibility 2019, estimated the potential of flexible loads during each hour is 4000 TWh.
- ✓ By 2040, the demand flexibility potential is predicted to touch 7000 TWh

Demand Flexibility Assessment

Characterization of the loads

Table 1: Categorization of residential loads

Category	Appliances	Capability	Operation Characteristics	
			Running mode	***Frequency of Use***
Adjustable loads	HVAC	Shed, shift, and modulate	Intermittently	Almost every day in winter and summer
	Electric water heaters	--do--	Intermittently	Running all- day
	Refrigerators	--do--	Intermittently	Running all- day
Shifting load	Dishwashers	shift	Finite cycle with sequential processing	Depending on the occupants, once or twice a day
	Washing machines	--do--	--do--	--do--
	Clothes dryers	--do--	--do--	--do--
Shedding loads	Lighting	Shed and modulate	Continuous	Every day

- ✓ Primary step is to understand the nature of controllable and uncontrollable loads in a residential building. This can be done by a load ***disaggregation process***
- ✓ Flexibility capabilities and operation characteristics of the residential loads are assessed (as in table1)
- ✓ All the flexible loads are categorized into adjustable, shifting, and shedding loads.
- ✓ The use of SMART METERS aids the process

Aggregated smart meter data and demand profiling

Using smart meters

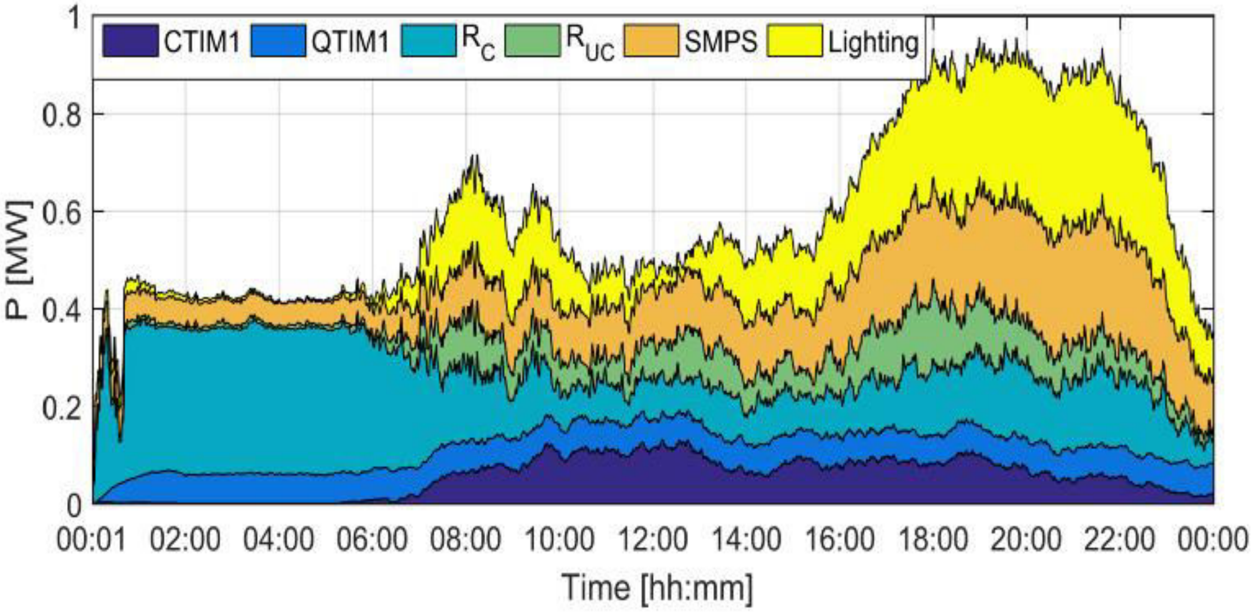

Fig. 1: Demand curve of all the controllable and uncontrollable equipment's using data from Smart meters [7]

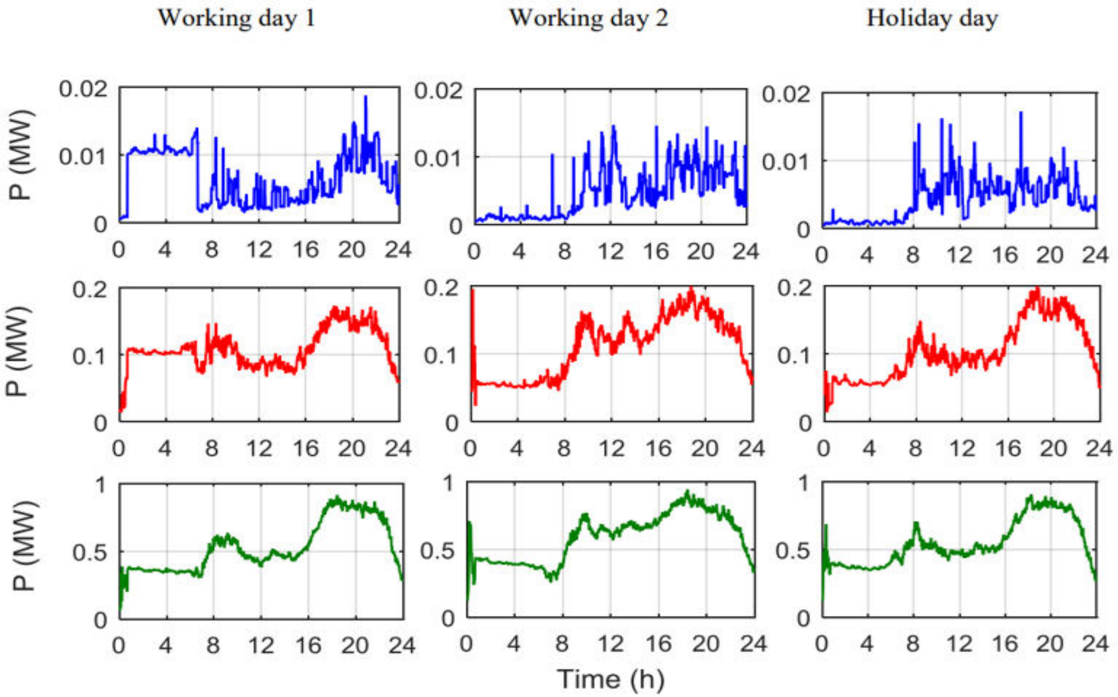

Fig. 2: Load curve from daily aggregated loads of 10 houses (first row), 200 houses (second row) and 1000 houses (third row) for working days and holidays [7]

Forecasting demand flexibility using smart meter data

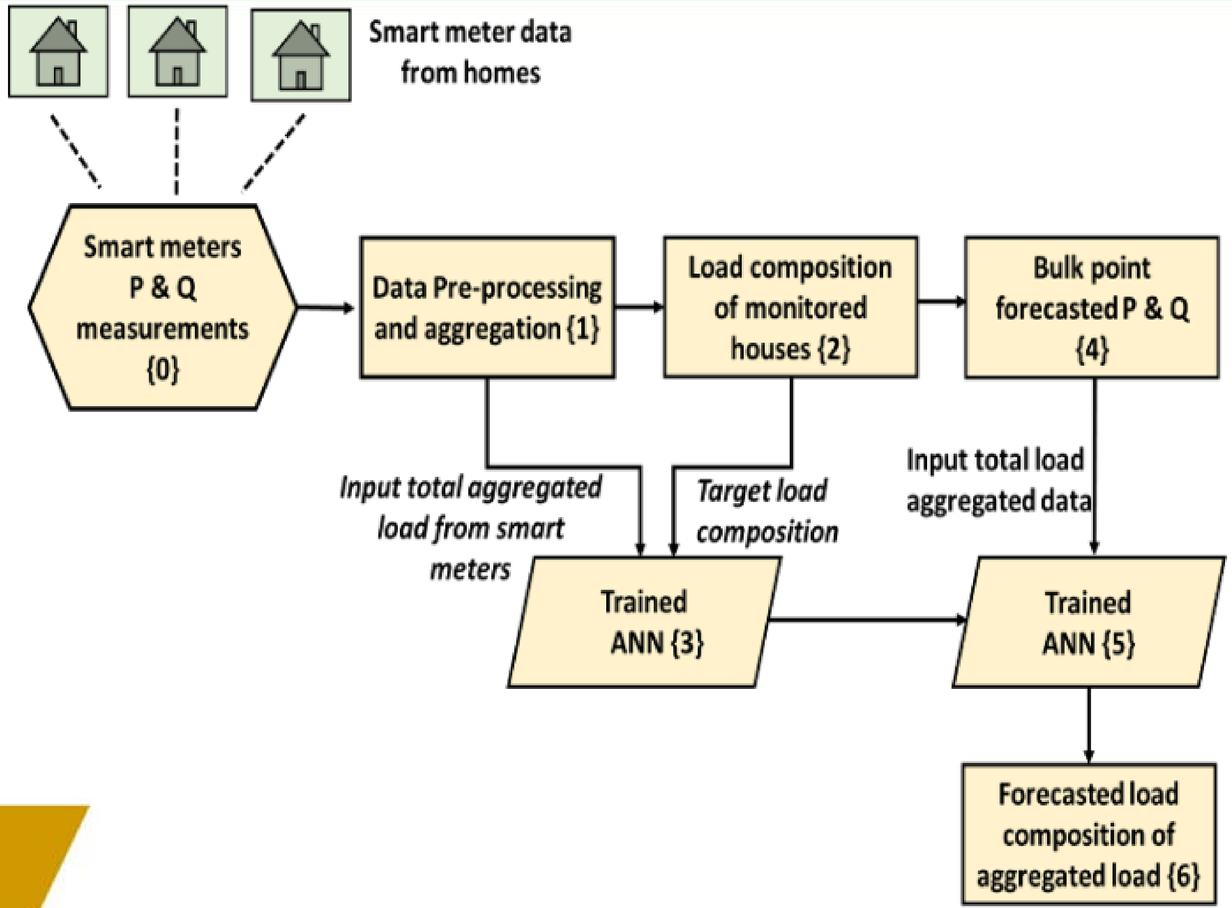

Fig. 3: Procedure for load forecasting of aggregated load using smart meters and ANN [6]

- ✓ In this method several smart meter users' data are used in aggregation to predict the overall aggregated load composition.
- ✓ It is estimated that with at least 5% of the smart meter population, it is possible to predict load composition at an aggregation point/substation with reasonably good accuracy.
- ✓ The work provided guidelines for demand flexibility estimation using submetering-enabled smart metering measurements and ANN.

Global Case Studies- Norway

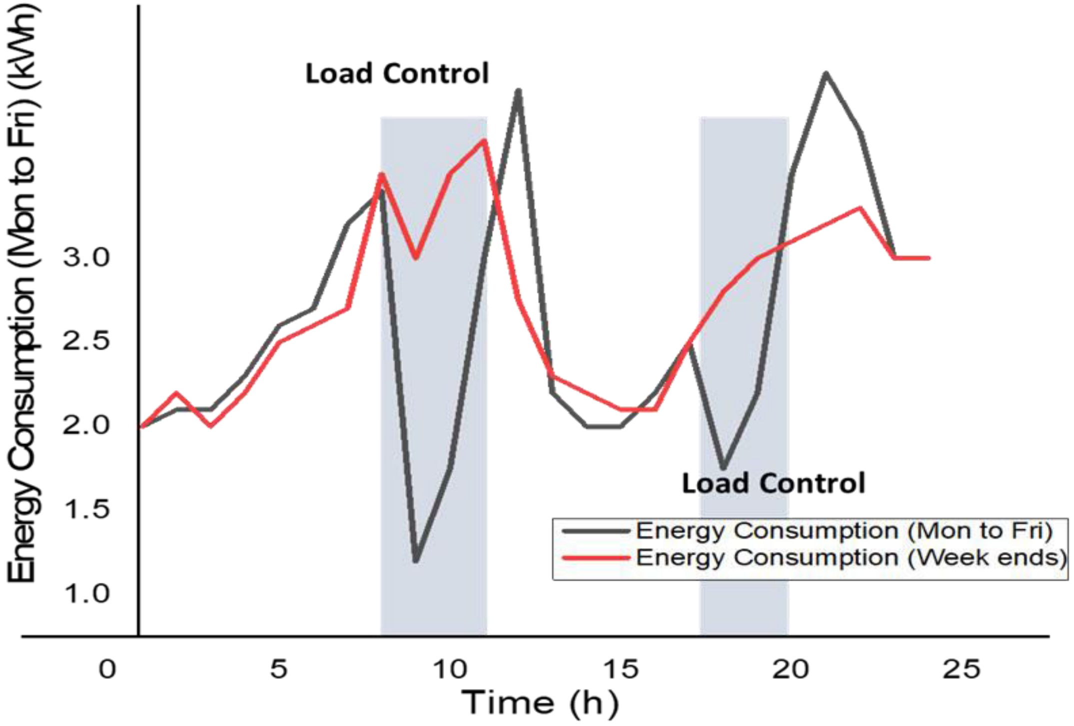

Fig. 4: Heating load profile of Norwegian household with direct load control in place [8]

E.g., Between morning, 09:00-11:00 hrs., and evening, 17:30 to 19:30 hrs., demand reduction takes place, and the peak is eliminated.

- ✓ The study is conducted among 40 households in Norway.
- ✓ These houses were connected to smart meters with a direct load control facility, and time-of-use tariff was used.
- ✓ When 50% of Norwegian consumers having heating load can offer a demand response potential of 1kW/h, it would result in an aggregated demand response potential of 1000MW/hr

Use Case - Belgium

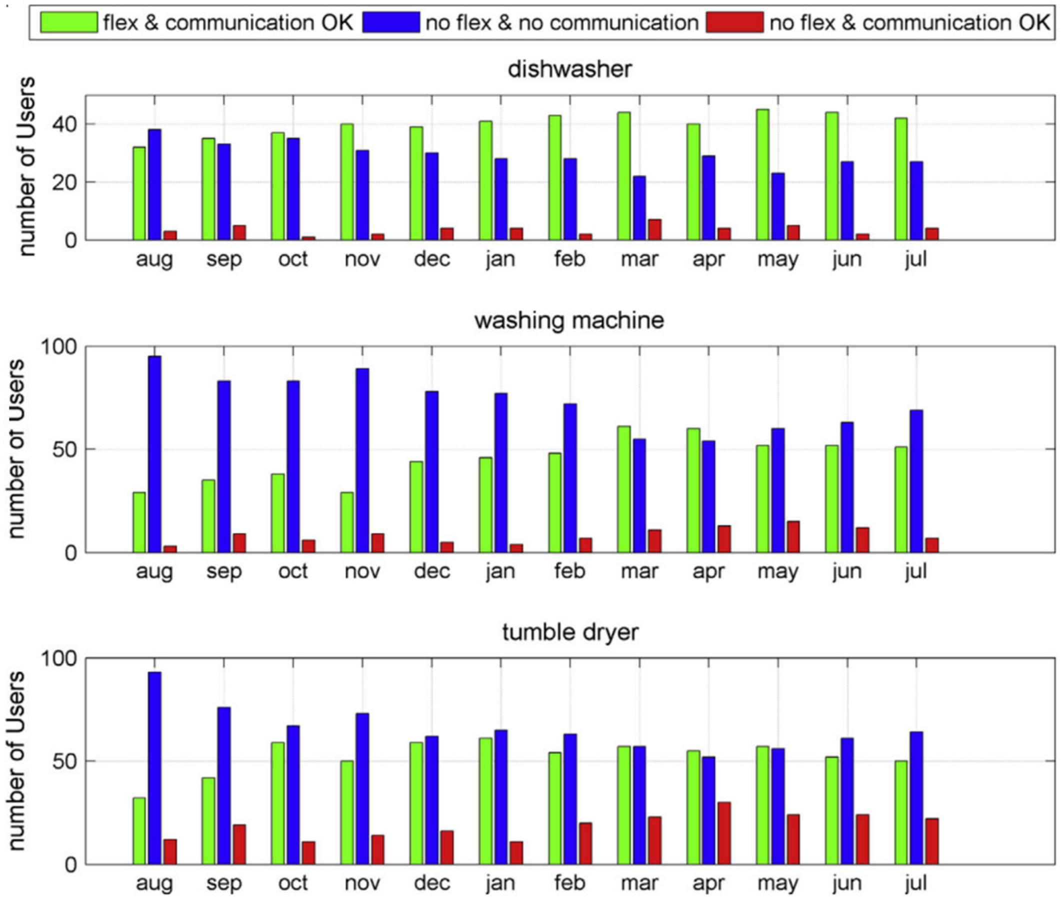

Fig. 5: Flexibility offered by consumers for three appliances dishwasher washing machine and tumble dryers [9]

- ✓ Belgium's demand response program was implemented among aggregated 239 houses.
  - Houses, were installed with smart meters and had smart home appliances
- ✓ Studied the flexibility potential of : - Washing machines, dishwashers and tumble dryers, domestic water heaters and electric vehicles
  - Poor consumer engagement resulted in reduced EV owners' interest in offering flexibility
  - IEA, the estimated demand flexibility capacity of Belgium in 2021 is 356 MW [3]

Use case - European demand response potential assessment

- ✓Study focused on the temporal availability of DR potential with geographical considerations
  - ***The theoretical DR potential of Europe was estimated. The minimum load reduction capacity available is 61 GW and the maximum load increase is 68 GW every hour of the year [10]***
- ✓ The work provided an overview of the sectoral share of average DR potential across the European countries (44 countries) for the industrial, residential, and tertiary sectors
- ✓ The largest residential share of DR potential is found in Ukraine, Malta, Lithuania, Lichtenstein, and Albania
- ✓ The country with the largest Industrial share of DR potential is Finland
  - *1360 MW- 9% of peak demand*
- ✓ The study categorized the 22 different loads in the country based on their minimum and maximum load reduction possible
  - ***The potential electric loads with a maximum difference (in MW) are space heating, air-conditioning and ventilation.***

The Key DF Enabling technologies and their estimated potential

Table 2: Enabling technologies and their flexibility potential [3]

Technology	2020 Deployment Status	2030 Deployment in line with Net Zero Scenario Milestones
Commercial and residential energy storage systems	3.7 GW	510 GW
Smart thermostats	30.4 million	231.5 million
Home energy management systems	4 million	32.7 million
Residential air conditioners	1.9 billion	2.6 billion
Heat pumps	180 million	600 million

Ref: IRENA 2019

Key Takeaways

- ✓ The research on Europe found that among residential appliances storage heaters, washing machines, tumble dryers and dishwashers are the devices with a maximum load reduction potential.
- ✓ As per IEA, by 2030, the prime contributor towards DF is buildings with a capacity of 250 GW. This target can be achieved if at least 10% of the building demand is flexible.
- ✓ The role of consumer as a stakeholder rather than a ratepayer is mandatory to materialize the projected target of DF. Consumers should be engaged by the utility, respective governments, and policymakers so that they join hands for grid modernization
- ✓ The total installed capacity of renewables in India has reached 100 GW. The revised target for 2030 is 450 GW of renewable energy (RE) capacity- This points towards the huge potential of Demand of Flexibility in the country
- ✓ Demand flexibility as a source of grid-scale energy storage is promising and demands in-depth research.

Key Takeaways

- ✓ From the NREL study in Bangalore on the scope of DF potential it is clear agricultural sector DF must be given importance in our country besides residential, commercial, and industrial sectors.
- ✓ Advantage of Agri-loads is that they aren't exposed to sub-daily operational constraints.
  - **Agri-consumers could offer more hours of flexibility per day without much sacrifice in their agricultural work**
  - **Recovery can last up to 24 hours, a more relaxed recovery time than any other end. Hence the power availability and energy availability per DR events are high**
  - **Each agricultural DR event can last from 3 - 7 hours against 0.5 to 2 hrs of daily DR events for other sectors**
  - India can economically achieve its clean power targets if this flexibility potential is exploited successfully
- ***In-depth research is needed to uncover the demand flexibility potential in a country and formulate energy policies***

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Thank You…..