XSICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

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Demand-Side Management Strategies, a Model of Expected Effects

Sandra Téllez-Gutiérrez, Oscar Duarte-Velasco

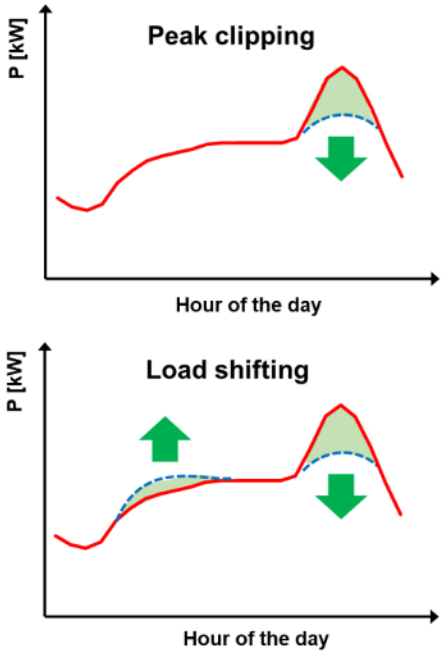
Universidad Nacional de Colombia
GRISEC Research Group

smtellezg@unal.edu.co

I. Demand-Side Management

Set of strategies aiming to modify electricity consumption patterns of end users connected to a smart grid, both in the time of use and in the quantity demanded of load, in order to optimize several aspects of the system:

- Electric system planning.
- Control and operation.
- Tariff and incentive scheme for energy consumption.
- Energy education.
- Regulation and normativity for local use.



I. Demand-Side Management

Traditional types of actions whereby electrical energy end user response:

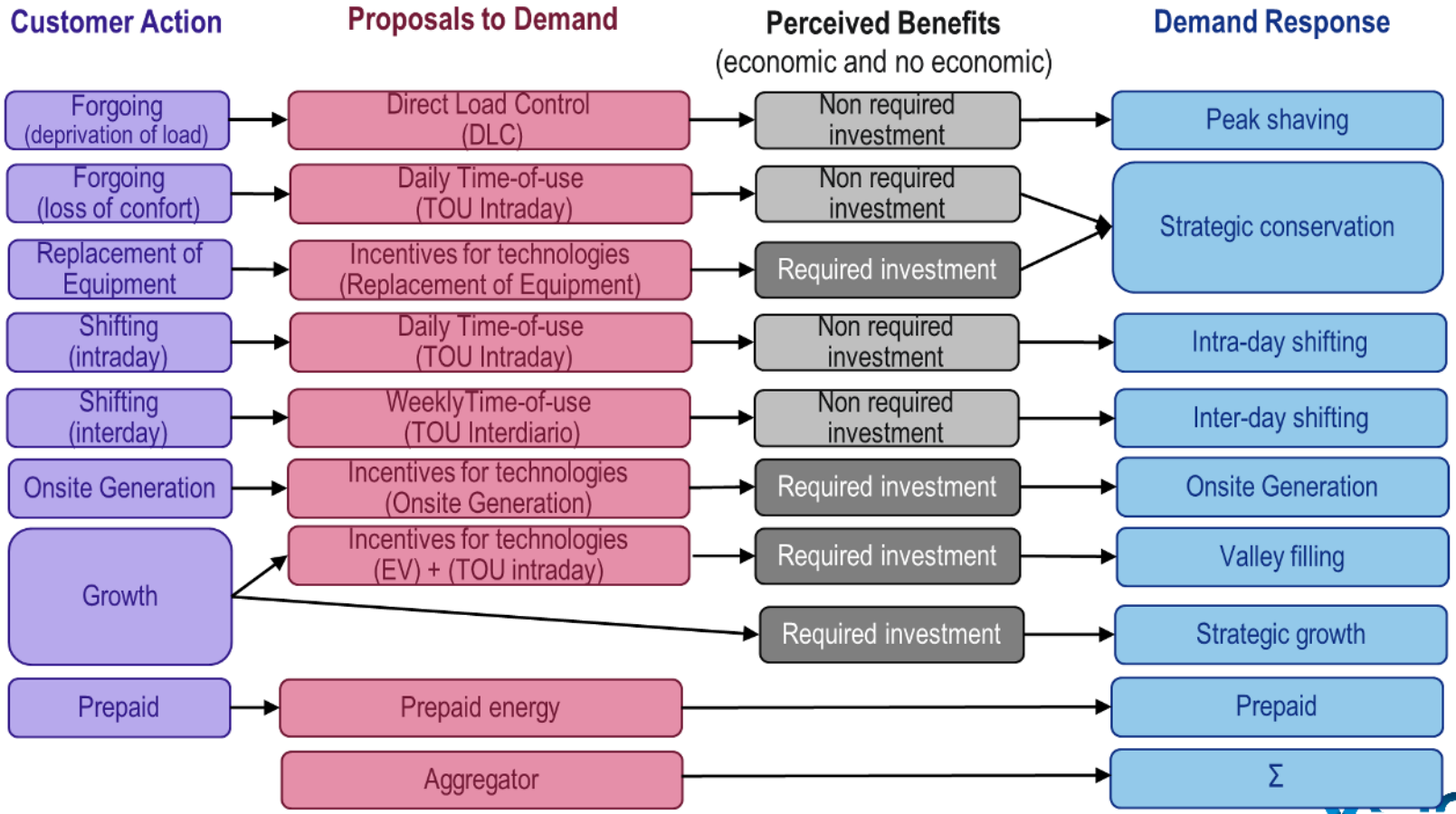
- Foregoing
- Shifting
- Onsite generation

Another customer actions are been proposed in this work:

- Growth
- Replacement of equipment
- Aggregation
- Prepaid

Energy cultures and education are essential elements to encourage and accelerate customer response

II. MODEL CONCEPTUALIZATION AND STRUCTURE



III. MATHEMATICAL MODELING WITH MODELICA

Interrelates variables, parameters and actions with the purpose of quantifying different relations inside the qualitative model and makes it possible to assess classic Response Demand techniques. Implementation on Modelica language includes:

- Daily energy e(t): $$e(t) = \sum_{1}^{NF} \frac{24}{NF}\, p(i,t) \quad [kWh]$$
- Actions: these are modelled as first-rate dynamic systems, with a growth rate of δ, measured in 1/months.

$$\frac{\delta_p(i,t)}{\delta_t} = \delta_c p(i,t)$$

- Action adoption rate: Dynamic action models have an action adoption rate by parameter δ. Each action has its own parameter that depends on energy culture.

$$\delta_a(t) = \overline{\delta_a} \times CE\,(t)$$

III. MATHEMATICAL MODELING WITH MODELICA

- Scaled-up load curve: This model is built on strong assumptions:
  - ✓ Culture refers to the knowledge an individual has on a topic.
  - ✓ Knowledge can be quantified by a numerical variable CE(t) $\in$ [0, 1].
  - ✓ It is possible to increase knowledge through educational activities.
  - ✓ Knowledge growth due to educational activities shows a behaviour connoted by logistic function.
  - ✓ The lack of educational activities leads to a decreased level of knowledge.
  - ✓ The diminishment of knowledge occurs at a lower rate than its growth.

$$CE(t) = CE(0) + x(t)\big(1 - CE(0)\big)$$

Where x(t) is an auxiliary variable that keeps a logistic behavior:

$$\frac{dx}{dt} = \Delta\uparrow - \Delta\downarrow$$

$$\Delta\uparrow = P(t) \times x(1-x)\delta_k \qquad \Delta\downarrow = \big(1 - P(t)\big) \times x(1-x)\frac{\delta_k}{v_k}$$

Where $\Delta\uparrow$ represents the growth of knowledge, $\Delta\downarrow$ represents the decrease in knowledge, P(t) is a variable in [0, 1] that represents the presence of an educational action and $v_k > 1$ is a factor that slows down the diminishment of knowledge, compared to its growth.

III. MATHEMATICAL MODELING WITH MODELICA

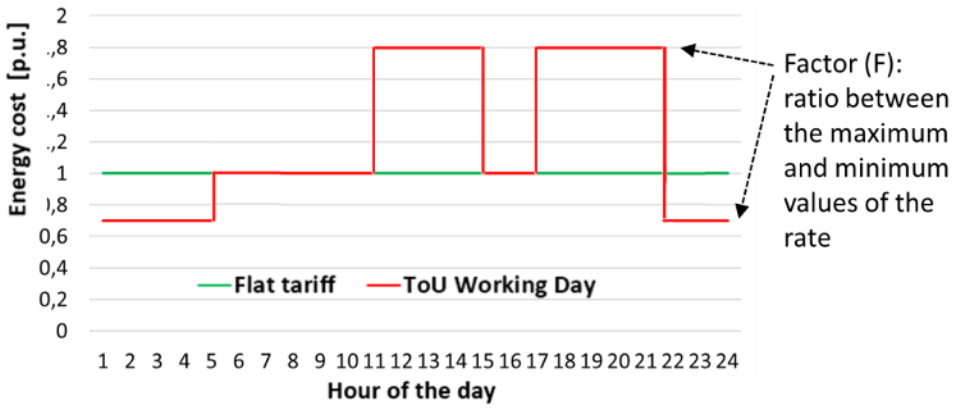
- Action feasibility: Each user must assess whether or not to adopt particular action This is a true or false decision In order to get in a point where the customer decides to adopt an action, it is needed that:
  - ✓ Utility as part of its portfolio offers to the customers the facilities to implement an action.
  - ✓ Customer do not have intrinsic barriers to implement it.
  - ✓ Customer understand how to adopt that action.
  - ✓ A positive cost/benefit ratio.
  - ✓ The diminishment of knowledge occurs at a lower rate than its growth.

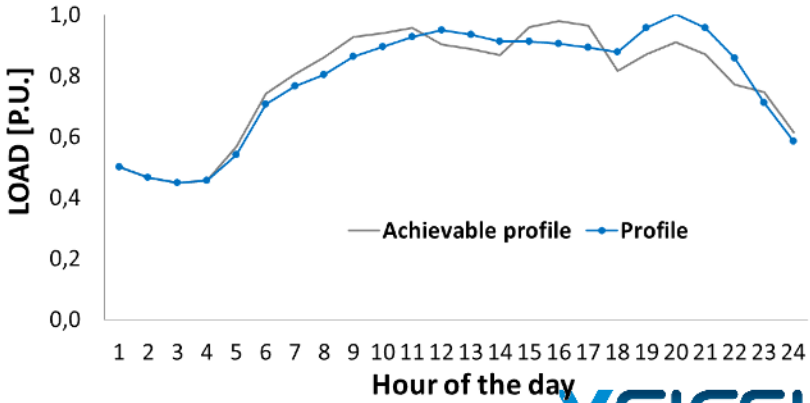
  The model to assess the feasibility to adopt an action j through boolean variable v_j (t) is

$$BCR(t) = \begin{cases} True \ \ if \ \ \dfrac{Benefit}{Cost} \times CE(t) > \mu \\ False \ if \ \ \dfrac{Benefit}{Cost} \times CE(t) \leq \mu \end{cases}$$

IV. MODEL SIMULATIONS

- Considerations:
  - ✓ Consumption patterns are associated with socio-cultural and characteristics of a particular context.
  - ✓ Consumption shifting and nonreduction can be considered simultaneously.
  - ✓ On peak hours, time of use tariff are offered to customers.
  - ✓ Factor (F) that relates the maximum and minimum tariff values.
  - ✓ From the consumption profile at the beginning of the simulation, an achievable profile is established which can be reached in response to the strategy.

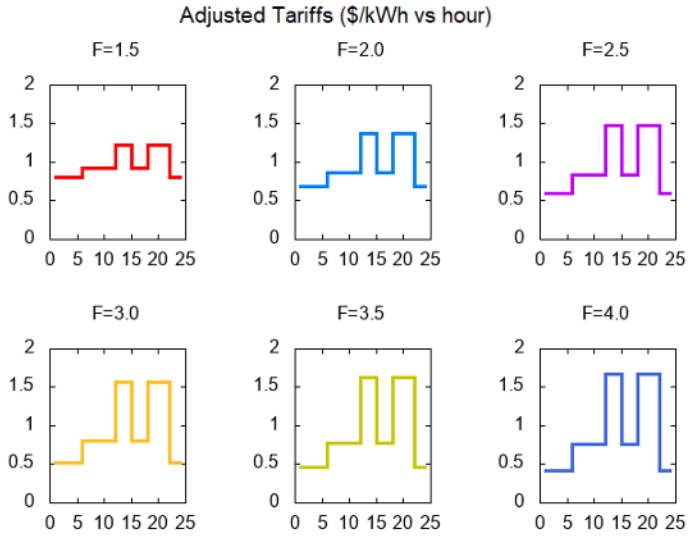




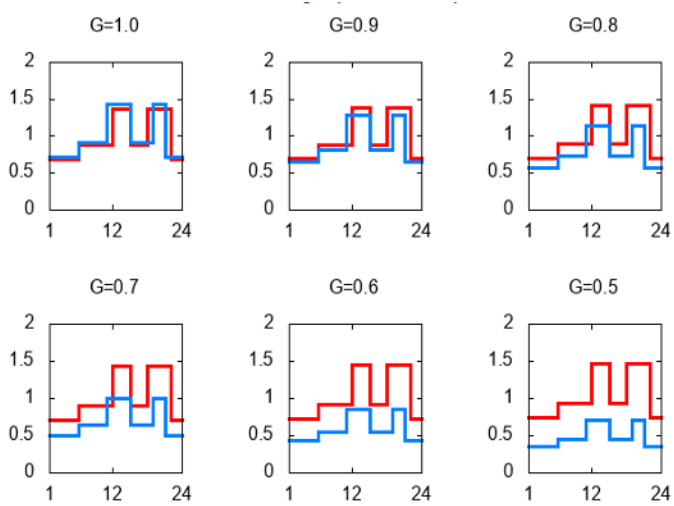
IV. MODEL SIMULATIONS

- ✓ From The tariff value must be set at the correct point so on day 1, the customer is charged with the same fee that he/she will be charged with according to the flat tariff.

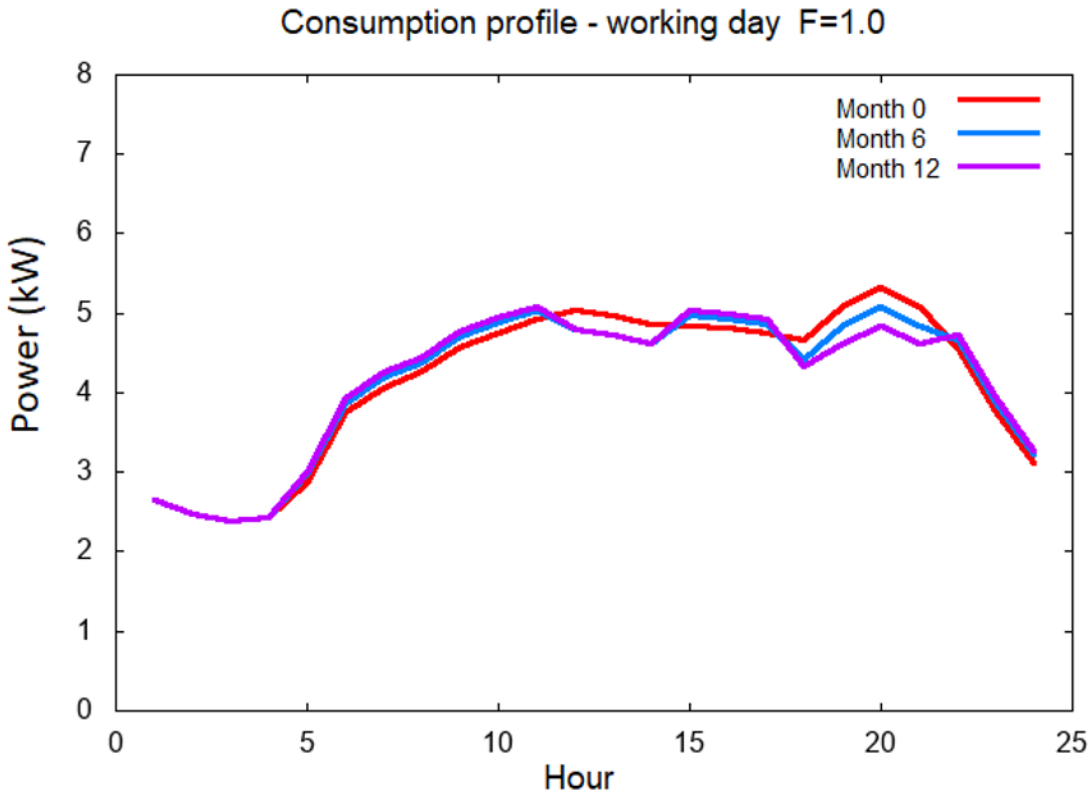
Intra-day case



Inter-day case

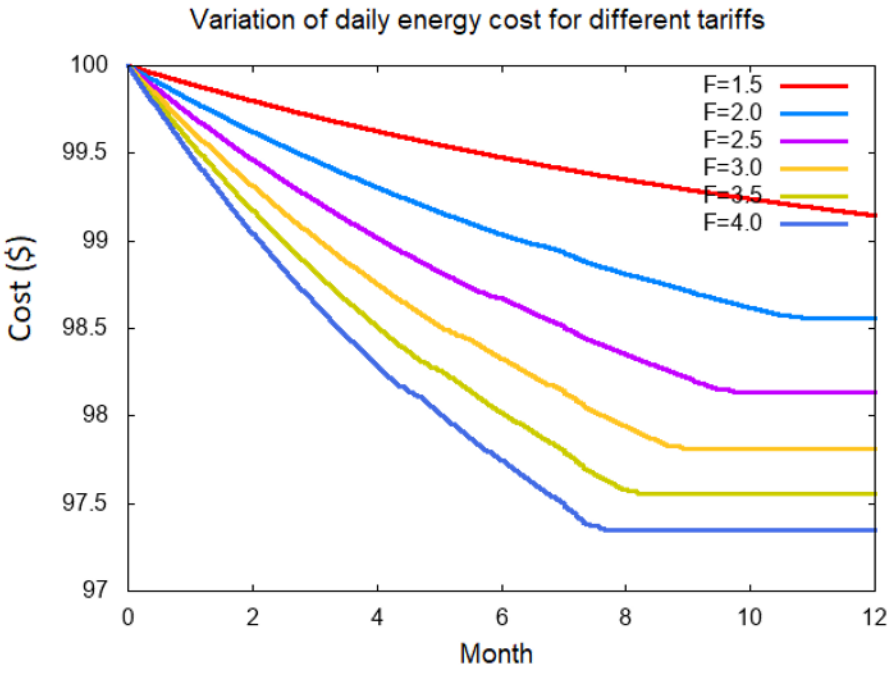


V. ACHIEVED RESULTS: Consumption profile

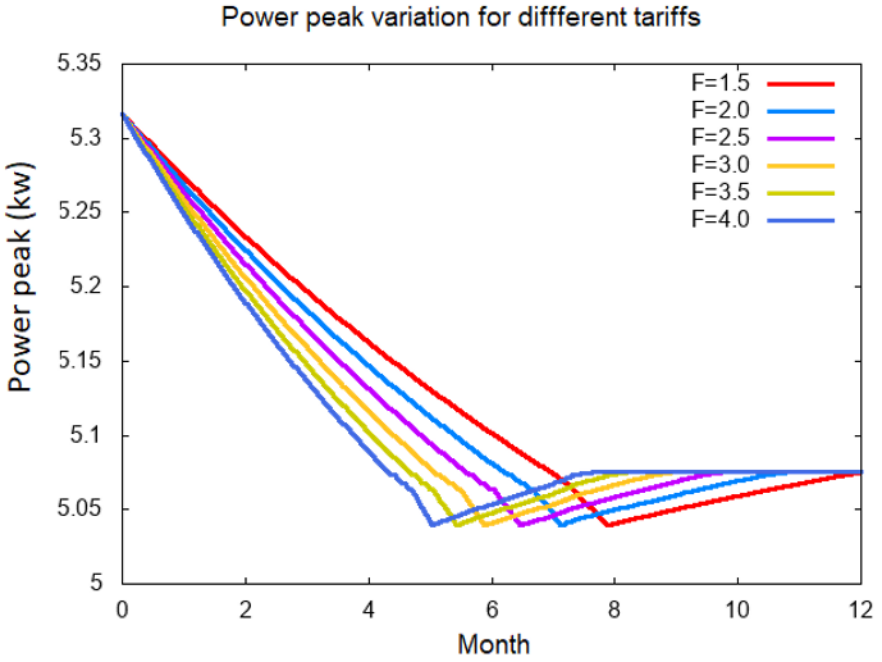


V. ACHIEVED RESULTS: Intra-day shifting

Variation of daily energy cost for different tariffs

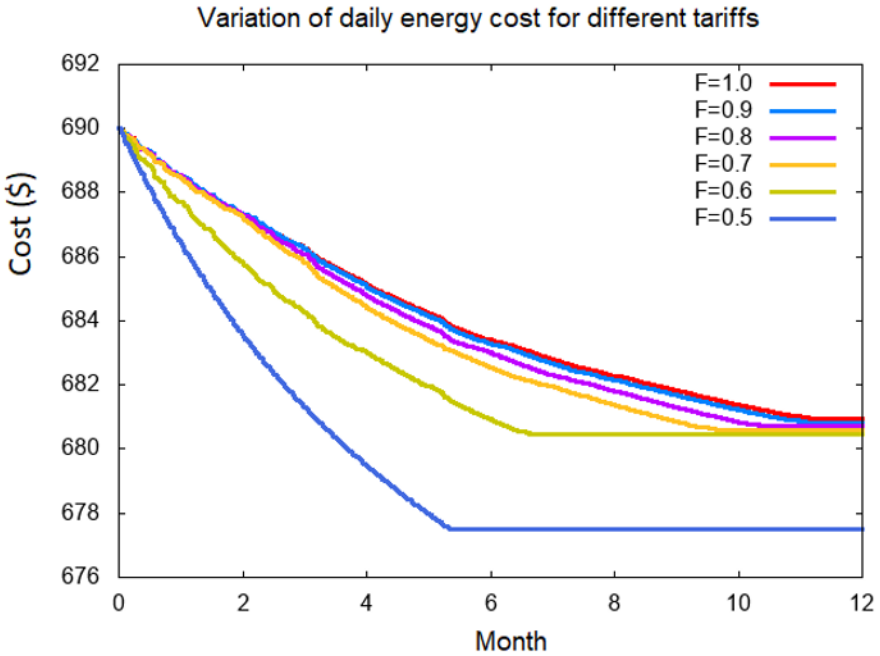


Power peak variation for different tariffs



V. ACHIEVED RESULTS: Inter-day shifting

Variation of daily energy cost for different tariffs



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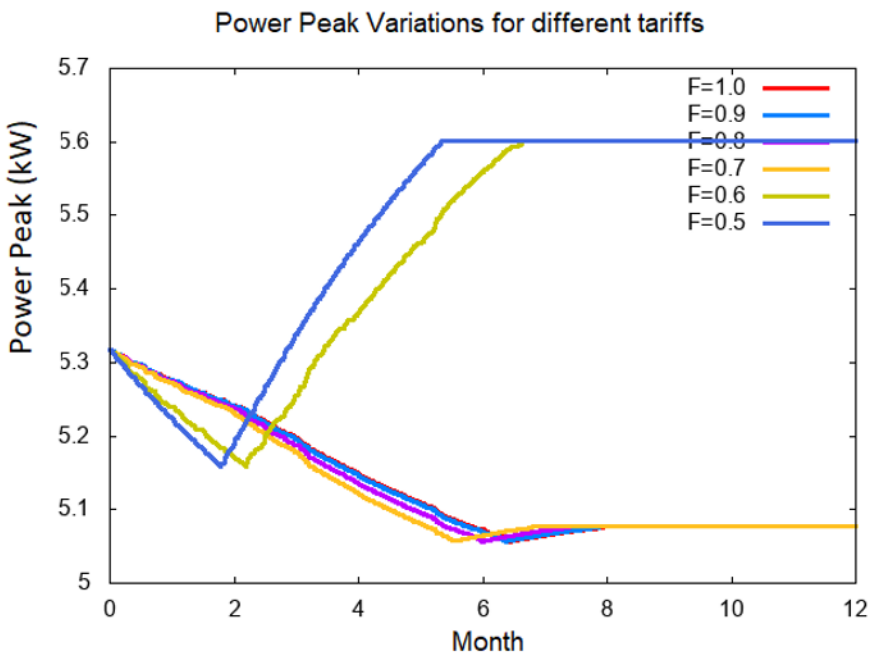
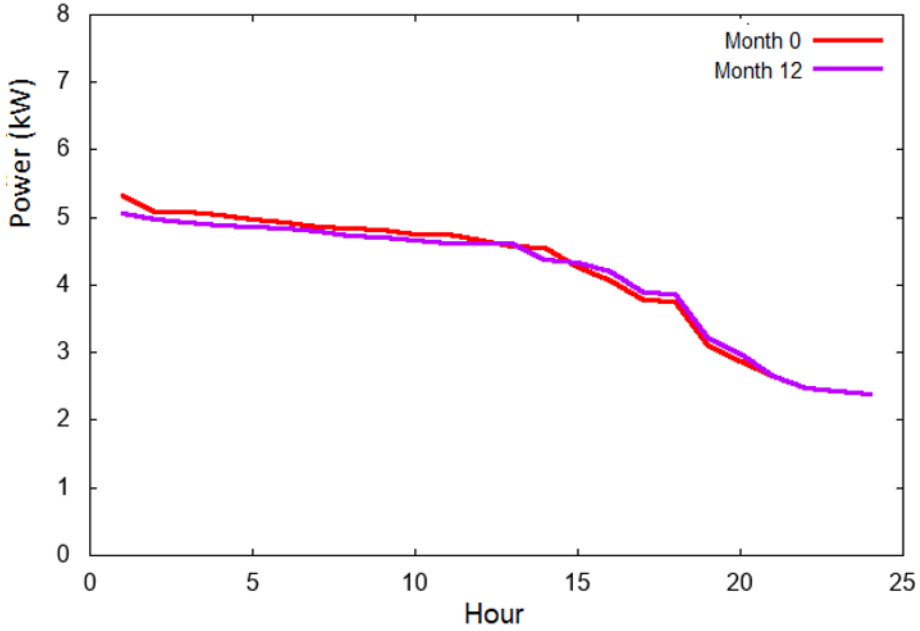


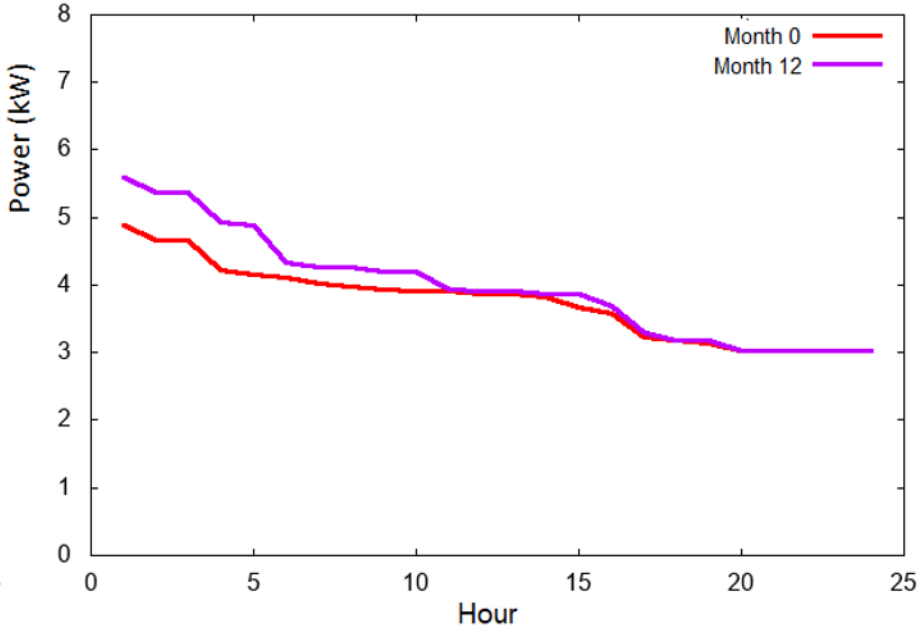
V. ACHIEVED RESULTS: Load duration curves

Inter-day shifting: initial and final duration curves

Weekdays



Holidays



VI. CONCLUSIONS

- A quantitative model to estimate effects of the response Demand-Side Management strategies from a set of users that have been characterized within their context.
- The results given by the model includes technical and economical aspects, for example modifications on daily consumption profile, load duration curve, energy consumption and cost. In addition, the model enables us to know the transition that the customer and the system follow to reach the strategy´s response.
- For intraday and inter-day shifting strategies, the model enables one to observe the tariff variation effects over customer daily consumption profile and its changes over time. The analysis made on model simulation results allows one to watch the strategy responses from customers in order to improve settings and to optimize them.