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Analysis and Design of a Power Consumed Limiter: Case of the Customers of National Society of Electricity of Congo/Likasi Town

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Abstract This article presents the fundamental interests and a design of a power limiter that allow the limitation of active power consumed by subscribers of a company that provides electrical power. It allows the National Company of Electricity (SNEL) to fix a power in kW subscribers, after determining their consumption. If a subscriber exceeds the subscribed or contracted power, electric power is cut off for five minutes. Upon resumption, if the subscriber has not decreased its consumption in less than a second, electric power is interrupted again; interruptions will not cease until the subscriber will not reduce consumption.

Keywords: *power limiter, active power, meter*

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1. Introduction

The flat-rate pricing, fraudulent connections, lack of awareness of SNEL subscribers in the operation of electric power are some problems that research in this article will help solve. In the field of current limiting, many devices exist. They range from regulated system to other methods (compensation series superconductors, fuses,…) [1-9].

Unlike fuses, circuit breakers, conventional pyrotechnic limiters, and superconducting fault current limiters based on the transition from the superconducting state (R=0) to the resistive state [10,11,12,13]; our limiter fixed current limit is not exceeded, and if this limit is reached it will follow an interruption; recovery will occur automatically if the charge is downgraded. The permanent increase in electrical energy requirements, both in quality and quantity, causes growth of the power of the installed equipment [14-20] where the interests of the power limitation.

Since the time of the Zairianisation, where the management of public companies in our country has gone national, SNEL connect new subscribers without meters. However, in the case of current claims, some subscribers are provided with the meters at their request, the meter being electromechanical an agent must periodically come to take the consumption index to establish the invoice [21,22,23,24]. But as the means of SNEL is limited, some customers are paying their own meters. Some timers placed with former subscribers are damaged, others are not calibrated, and others burned following the increases in load among subscribers. Due to lack of electric power meters for ordinary subscribers SNEL, it proceeds to the flat rate of the electrical energy consumed by subscribers. To do this, after a period of 5 years, SNEL organizes itself to identify the receptors in certain subscribers to estimate the power they consume. Thus we speak of the estimated or flat rate. This estimate is made on part of consumers. Thus subscribers located in downtown are classified into 2 residential tariff (Tariff 34); those located on the outskirts of downtown neighbourhoods are classified into residential pricing 1 (Tariff 33) and those located at the end of the city are divided into social tariff (Tariff 32). In fact, the pricing longer reflects the geographical location of subscribers, instead of being aligned with the electrical power they consume.

A fraudulent connection is the one that is not officially recognised by the provider (SNEL). Since the electricity pricing are fixed, the cost of the bill is not related to the consumption of electricity, some official subscribers (those who are recognised by the SNEL) connect their neighbourhoods without the knowledge of SNEL. All subscribers not recognised by SNEL are fraudsters, and the electrical wires that link them to the SNEL network are called fraudulent connections (the electricity theft) and constitutes an act contrary to the law. The fraudsters are paying their energy consumption to the official subscribers this constitutes a shortfall for the SNEL.

This article allows SNEL subscribers not to exceed the power subscribed by it, so to avoid the estimated pricing, fight against fraudulent connections, and get subscribers to the behaviour of the alternate use of household electrical appliances with high consumption. The rest of this paper is organized as follows: In section II the materials and methods used for this study system are explained. Section III gives the results. A detailed discussions constitutes the section IV. Finally, the conclusion of the work is summarized in section V.

2. Materials and Methods

A. Materials

To realize the model of the limiter, we used electronic components, measurement devices and receivers.

B. Methods

To gather information on consumption and pricing of electricity, we made visits to various departments of the SNEL/LIKASI, and review the electrical power limiters. We interviewed the staff of the distribution network of SNEL/LIKASI during the period from July to September 2015. We then compared the power consumed by subscribers of SNEL to billing demand, and we also observed how subscribers SNEL/LIKASI behave when billing. To design the power limiter, we conducted by the experimental method, using a model developed the power limiter. In our testing, we powered through the limiter the receivers, we identified the different power values which the limiter has responded.

3. Results

The power limiter design was based on the following electronic circuits:

- The rectifier-filtering: which allows to supply the limiter circuit with a stable voltage and provides the electrical power necessary for its operation;
- The pre-amplifier and the regulator: it is not supplied (attacked) by an alternating signal to be amplified, but amplifies all variations when there is variation of the supply voltage, following an overload downstream of power limiter. The adjuster which is nothing other than a potentiometer, is used to adjust the current (load) from which the preamplifier transistor reacts;
- The timer: constituted by capacitors and resistors, allows to keep the electrical energy, to control the circuit located downstream, even if upstream the transistor is blocked, because the pulse that causes the overload is too short;
- The electromagnetic relay: this allows to make the interface between the power limiter and the electrical circuit of the subscriber by performing the galvanic isolation, because the system studied is powered by a DC voltage of +/- 12V DC, while the subscriber's electrical circuit is powered at 220V AC.

The operation of the whole is given in the discussion. In this experiment, we have reached the electronic diagram of Figure 1.

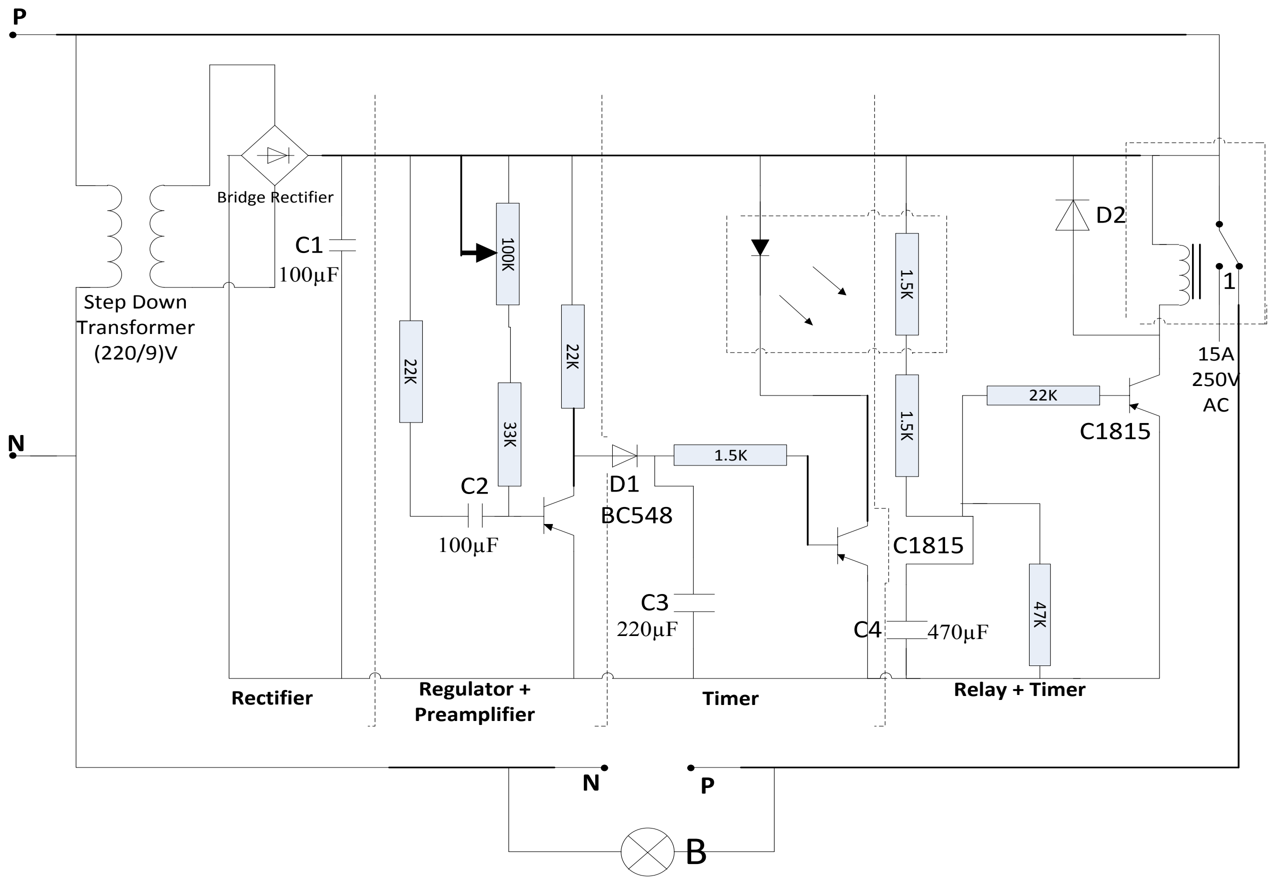

Figure 1. Diagram of power limiter

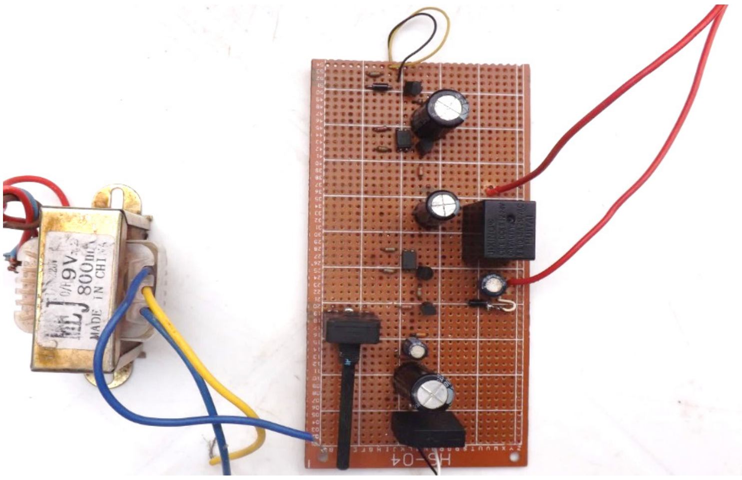

Figure 2. Power Limiter and Step-down Transformer

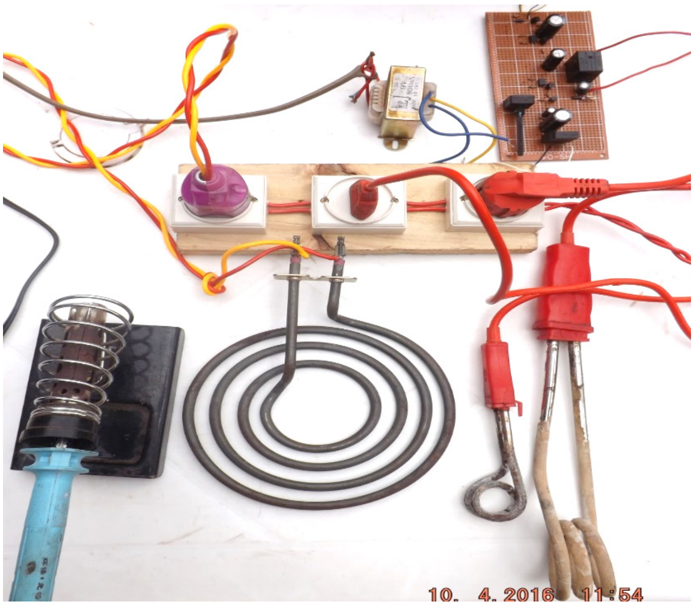

Figure 3. Power Limiter and Device Receptors

In Figure 2, we find the power limiter and its step down transformer.

In Figure 3, the power limiter is presented with connections to several receivers.

The lamp was used in parallel with the circuit and the charges for powers from 850 to 2500W, for potentiometer values ranging from 18 to 100 kW; the potentiometer 100 kW, the limiter is sensitive to low powers: he reacts to powers less than 850 W; the limiter has responded to a resistance value of the potentiometer 18 kW, in keeping the power of receivers in our disposal. Over the resistance potentiometer decreases, the limiter is activated by a great power.

4. Discussion

A. Power Consumption and Billing

a. Pricing Based on Subscribed Power

The pricing of the electricity from SNEL are very flexible and varied according to the consumers. All the consumers are divide into categories according to the technical gene of the power demand. The low voltage subscribers are split into two classes, namely:

- Ordinary low voltage consumers: which are categorised according to the energy they consume for one month and are classified into three tariffs;
- Basic low voltage consumers: constituted by the owners of bakery, mill, cold room, those using motors, hotels, shops (code 36 and 37).

The low voltage consumers are categorised as follows:

- Tariffs 32 or social: for those consuming less than 100 kWh;
- Tariffs 33 or residential 1: for those consuming between 101 to 600 kWh;
- Tariffs 34 or residential 2: for those consuming more than 600 kWh;
- Tariffs 36 or basic low voltage consumers using motors;
- Tariffs 37 or basic business low voltage consumers.

The power demand for Tariffs 36 and 37 are the same but the cost of consumption depends on rates in kWh.

b. SNEL Billing

As mentioned above, for the pricing of type of subscribers and their tariffs, the billing obeys also to this principle while giving the cost of rates in kilowatt-hours. The cost of rate is fixed by the SNEL direction according to the variation in the rate of US dollars in referring to the Commercial Bank of Congo (BCDC). In April 2016, the rate was 963.86FC (FC: Congolese Francs) and for may 2016 was 970.13FC (equivalent to 1US $). For this study, the month of may was taken as sample because of the simplicity of the verification of evolution of tariff rates.

Table 1. Pricing for domestic low voltage, residential, motors users and business owners

Ordinary Low Voltage		
Tariffs	Rate in kWh/month	FC/month
32 or Social	1 to 100	2571.01
33 or Residential 1	1 to 100	38.65
	101 to 200	38.23
	201 to 300	37.84
	301 to 400	37.45
	401 to 500	37.06
	501 to 600	36.67
34 or Residential 2	1 to 600	86.15
	601 to 800	85.28
	801 to 1000	84.41
	1001 to 1200	83.53
	1201 and more	82.66
Basic Low Voltage		
36 or Motors users	1 to 50	7325.33
	51 to 200	146.51
	201 to 500	144.58
	501 to 1000	143.62
	1001 to 1500	141.62
	1501 and more	140.72
37 or Business Owners	1 to 50	5349.45
	51 to 200	106.99
	201 to 500	106.02
	501 to 1000	105.06
	1001 to 1500	104.10
	1501 and more	103.13

Suppose a subscriber has consumed 470kWh a month. The pricing structure of its consumption will deducted as follows:

- Tranche of consumption in kWh
  As indicated in Table 1, this subscriber is in tariff 33, its monthly consumption is less than 600kWh and its consumption varies from 401 to 500.
- The cost in FC of kWh consumed is deducted as follows:
  From 1 to 100 = 38.65FC → 38.65 x 100 = 3865FC
  From 101 to 200 = 38.28FC → 38.28 x 100 = 3828FC
  From 201 to 300 = 37.84FC → 37.84 x 100 = 3784FC
  From 301 to 400 = 37.45FC → 37.45 x 100 = 3745FC
  From 401 to 500 = 37.06FC → 37.06 x 100 = 3706FC
  The total gives: 18,928FC (VAT included).

This is the amount that this subscriber will pay for its consumption of 470kWh.

B. Operation of the Limiter

The limiter is installed after the switch SNEL of subscribers, it is provided primarily an adjuster (potentiometer) for fixing a power that the subscriber cannot exceed. If the power consumption becomes greater than the fixed power, electric power is interrupted at the customer for five minutes. Unlike the current limiting inductive superconducting fault, where one seeks the rapid limit fault currents [25-36].

The transformation ratio of a transformer being constant, when you plug a high load on the line, there is decrease in power at the primary and secondary; the value of the voltage at the rectifier output also decreases. Depending on the value of preamplifier basis of resistance; the transistor thereof or conduit remains blocked, the potentiometer allows adjustment of the resistance at which the transistor conducts; by setting its value, adjusting the value of the power from which the limiter responds.

If the preamplifier transistor conducts, the diode D1 is conducting, the capacitor C sets a delay in the conduction of the second transistor after the saturation of the latter the photodetector device is supplied and supplies the second timer; its transistor, by saturating feeds the electromagnetic relay. It draws its contact to the position 1, the power is off in the subscriber circuit. But as the capacitor of the second timer keeps a load, the transistor of the second timer and the relay placed in its collector remain powered, after five minutes, the capacitor loses its charge, the transistor of the second timer is blocked again, the relay is turned off, as there is no power, the coil is no longer excited, the relay contact is no longer attracted and resumes its rest position. Power is restored in the subscriber circuit, but if the device (or devices) that has (have) caused (s) the voltage drop is (are) always connected (s), in a few milliseconds the limiter is new, and the electric power is interrupted again, electric power will be stable only when the subscriber has reduced its load by disconnecting the (s) unit (s) to strong (s) consumption. Another important feature of the power limitation is their response time should be as short as possible [37].

The potentiometer sets the value not to exceed not turn on the limiter. In fact, it is he who makes it possible to share the limiter setting the value of the resistance, and thus the tension that allows the first transistor to drive. More the resistance value of the potentiometer, the greater the limiter is switched on by low power, because a great resistance creates a voltage drop, thereby allowing the transistor of the preamplifier driving quickly; while a small resistance creates a lower voltage drop, so in this case, the limiter responds to big powers.

C. Electrical Power Quantified by SNEL

We speak often of watts (W), kilowatt (kW), watt-hours (Wh) and kilowatt hours (kWh) without necessarily fully understand what it is. Here is a little reminder of the meaning of these units. A watt is a unit of power. It expresses the instantaneous energy power used by a device. Kilowatt is a multiple of watt. 1 kilowatts, equivalent to 1000 W; therefore a device that consumes one kilowatts used 1000 W (1000 joules per second). The watt-hour allows for him to measure the energy consumed over a given period (1 hour) by a device consuming 1 W. The kilowatt hour is the multiple. It corresponds to the energy consumed in 1 hour by a unit displaying a consumption of 1000 W [38].

Despite a fixed price, without meter, charging the electric energy consumed by subscribers of SNEL is based on an estimate; customers SNEL therefore have no interest in rational use electricity because they have nothing to lose. In addition to some customers of SNEL do not hesitate to be distributor by working to fraudulently connect some of their neighbors; this is a loss for SNEL. Other simultaneously use multiple electrical appliances to high consumption, instead of alternate employment.

D. Power Consumption by Customers of SNEL

We wanted to compare the consumption of some appliances, especially to know what cost this represents the monthly electric bill? Obviously, some factors are likely to vary power consumption of the devices. The composition of a family is an alternative to be considered, including the use of appliances such as irons or hot water heater, requiring more use cycles in a large family. For information, here in Table 2, the average power in watts and estimated for different devices:

Table 2. Estimated Power of Different Appliances

Appliance	Medium Power	Maximum Power
Fridge 50L	100W	300W
Fridge 200L + Freezer	300W	700W
Hotplate	150W	---
Electric Oven	2500W	---
Microwave	800W	---
Coffee Maker	1000W	---
Mixer	200W	500W
Fountain Water Heating/Refreshing	400W	1200W
Iron	1000W	---
Mobile Phone Charger	5W	---
TV CRT	10W	100W
TV LCD	5W	200W
TV Plasma	5W	300W
PC + CRT	50W	150W
PC + Flat Screen	5W	80W
Laptop	5W	30W
Printer-Copier	10W	800W
Scanner	10W	600W
WIFI Router	5W	---
Fan	50W	60W
Air Conditioner	500W	1200W

These data are only indicative since it is estimated that average. The real power of the appliance in question is indicated on the nameplate or it's manual. On the basis of the second table, it is difficult to reach 5 kWh (5000Wh) in domestic pricing, when rationally operates the electric current. The power limiter will significantly reduce power consumption and cost of monthly bills subscribers SNEL. Power can be limited to the example of Belgium minimum Power: 2300W (230V=10A). Placement/Removal: the responsibility of the group SIBELGA [39]; but the group SIBELGA limiter is activated manually in case of interruption. In addition, all electronic components to achieve our limiter only worth 12,000 Fc (≈13 $).

The power limiter also helps fight against faults, short circuit currents are harmful to the network or for thermal reasons (fusion drivers, degradation of insulation) or for mechanical reasons because of induced deformations by electromagnetic forces, either for reasons of cost as they contribute to premature aging of the material [40-47].

5. Conclusion

This article has focused on the design of an electronic circuit to limit the power consumed by customers of suppliers of electric power for the reasons outlined in the introduction. The limiter model designed to work well in the laboratory, it only remains to the test at a subscriber. Indeed, the limiter has responded to the charges for power ranging from 850W to 2500W. The survey shows the existence of loads up to 10000W in the semi-industrial domestic pricing SNEL/LIKASI. But the electromagnetic relay of our limiter is limited to 3750W; it must be replaced for higher loads. Our limiter has been tested in single phase; for a three-phase installation, three single phase transformers connected together to form a three-phase transformer and a three-phase electromagnetic relay will be necessary. In these pages we have not addressed the protection of our power limiter after installation. The power limiter can be used by all electrical energy suppliers; it can be used to subscribers that have an electrical energy meter for helping controlled their consumption.

References

[1] T. Yazawa, K. Koyanagi, M. Takahashi, K. Toba, H. Takigami, M. Urata, Y. Lijima, T. Saitoh, N. amemiya, Y. Shiohara, and T. Ito, "Development of 6.6kV/600A superconducting fault current limiter using coated conductors", Physica C, vol. 469, pp. 1740-1744, 2009.

[2] D. Tournier, "Conception, Réalisation et Caractérisation d'un composant limiteur de courant commandé en carbure de silicium et son intégration système," Thèse de Doctorat, Institut National des Sciences Appliquées de Lyon, 2003.

[3] P. Tixador, and A. Badel, "Superconducting fault current limiter optimized design", Physica C, vol. 518, pp. 130-133, 2015.

[4] L. Chen, Z. Li, C. Deng, H. Liu, Y. Weng, Q. Xu, Z. Wu, and Y. Tang, "Effects of a flux-coupling type superconducting fault current limiter on the surge current caused by closed-loop operation in a 10kV distribution network", Int. J. of Electrical Power and Energy Systems, vol. 69, pp. 160-166, 2015.

[5] G. Didier, CH. Bonnard, T. Lubin, and J. Leveque, "Comparison between inductive and resistive SFCL in terms of current limitation and power system transient stability, Electric Power Systems Research, vol. 125, pp. 150-158, 2015.

[6] C. Zhang, Y. Tang, S. Liang, L. Ren, Z. Wang, and Y. Xu, "Computational study on the steady state impedance of saturated-core superconducting fault current limiter", Physics Procedia, vol. 81, pp. 195-198, 2016.

[7] J. Zhu, X. Zheng, M. Qiu, Z. Zhang, J. Li, W. Yuan, "Application simulation of a resistive type superconducting fault current limiter (SFCL) in a transmission and wind power system", Energy Procedia, vol. 75, pp. 716-721, 2015.

[8] A.R. Devi,, and J.N. Kumar, "Simulation of resistive super conducting fault current limiter and its performance analysis in

three phase systems", Int. J. of Engineering Research and Technology, vol. 2, Is. 11, pp. 411-415, November 2013.
[9] J.G. Lee, U.A. Khan, H.Y. Lee, S.W. Lim, and B.W. Lee, "Mitigation of commutation failures in LCC–HVDC systems based on superconducting fault current limiters", Physica C: Superconductivity and its Applications, pp. 1-4, 2016.
[10] I.G. Im, H.S. Choi, and B.I. Jung, "Limiting characteristics of the superconducting fault current limiter applied to the neutral line of conventional transformer", Physica C, vol. 494, pp. 339-343, 2013.
[11] A. Allais, "La protection de réseau : Les limiteurs de courant supraconducteurs," Nexans France, Conférence SEE: la supraconductivité dans les systèmes électriques, Lyon le 18 Octobre 2012, 23 pages.
[12] C.S. Song, H. Lee, Y.S. Cho, J. Suh, and G. Jang, "Implementation of superconducting fault current limiter for flexible operation in the power substation", Physica C, pp. 158-162, 2014.
[13] L. Ye, and A.M. Campbell, "Case study of HTS resistive superconducting fault current limiter in electrical distribution systems", Electric Power Systems Research, vol. 77, pp. 534-539, 2007.
[14] U.A. Khan, J.G. Lee, I.J. Seo, F. Amir, and B.W. Lee, "Feasibility analysis of a novel hybrid-type superconducting circuit breaker in multi-terminal HVDC networks", Physica C, vol. 518, pp. 154-158, 2015.
[15] J.G. Lee, U.A. Khan, J.S. Hwang, J.K. Seong, W.J. Shin, B.B. Park, B.W. Lee, "Assessment on the influence of resistive superconducting fault current limiter in VSC–HVDC system", Physica C, vol. 504, pp. 163-166, 2014.
[16] Y. Cointe, "Limiteur Supraconducteur de Courant Continu," Thèse de Doctorat, Institut National Polytechnique de Grenoble, 13 Décembre 2007.
[17] H. Radmanesh, S.H. Fathi, and G.B. Gharehpetian, "Novel high performance DC reactor type fault current limiter", Electric Power Systems Research, vol. 122, pp. 198-207, 2015.
[18] J. Shi, Y. Tang, C. Wang, Y. Zhou, J. Li, L. Ren, and S. Chen, "Active superconducting DC fault current limiter based on flux compensation", Physica C, pp. 108-112, 2006.
[19] J.G. Lee, U.A. Khan, S.W. Lim, W.J. Shin, I.J. Seo, and B.W. Lee, "Comparative study of superconducting fault current limiter both for LLC–HVDC and VSC–HVDC systems", Physica C, vol. 518, pp. 189-153, 2015.
[20] Y. He, T. Jiang, C.Y. Du, C.B. Li, A.G. Wu, and Y. Xin, "Control system modelling and simulation of superconducting current limiter with saturated iron core controlled by DC bias current", IEEE Trans. on Applied Superconductivity, vol. 24, No. 5, Oct. 2014.
[21] F. ŞTEFĂNESCU, "Etude Numérique d'un Limiteur de Courant de Défaut Supraconducteur Inductif, " 8th International Conference on Applied and 10th Theoretical Electricity and Symposium on Cryoelectrotechnics and Cryogenics, Boile Herculane, 26-28 October 2006, Annals of the University of Craiova, no.30, 2006, pp. 378-381.
[22] Y.J. Kim, K.S. Chang, H.C. Jo, Y.S. Yoon, J.H. Lee, H. Lee, and T.K. Ko, "Recovery estimation for over-current test of non-inductive fault current limiters using numerical analysis", Cryogenics, vol. 51, pp. 261-265, 2011.
[23] W.T.B de Sousa, A. Polasek, R. Dias, C.F.T. Matt, and R. de Andrade Jr, "Thermal-electric analogy for simulations of superconducting fault current limiters", Cryogenics, vol. 62, pp. 97-109, 2014.
[24] B. Mahdad, and K. Srairi, "Application of a combined superconducting fault current limiter and STATCOM to enhancement of power system transient stability", Physica C, vol. 495, pp. 160-168, 2013.
[25] W. Gans, A. Albertini, and A. Longo, "Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland", Energy Economics, vol. 36, pp. 729-743, 2013.
[26] J. Carroll, S. Lyons and E. Denny, "Reducing household electricity demand through smart metering: The role of improved information about energy saving", Energy Economics, vol. 45, pp. 234-243, 2014.
[27] J.L. Viegas, S.M. Vieira, R. Melicio, and V.M.F. Mendes, "Classification of new electricity customers based on surveys and smart metering data", Energy, vol. 107, pp. 804-817, 2016.
[28] F. Klopfert, "L'apport des compteurs intelligents à une consommation plus durable de l'électricité," Thèse de Maitrise, Université Libre de Bruxelles, 4 Aout 2008.
[29] B. Mack, and K.T. Mai, "An action theory-based electricity saving web portal for households with an interface to smart meters", Utilities Policy, pp. 1-13, 2016.
[30] S. Marrone, and U. Gentile, "Finding resilient and energy-saving control strategies in smart homes", Procedia Computer Science, vol. 83, pp. 976-981, 2016.
[31] S. D'oca, S.P. Corgnati, and T. Buso, "Smart meters and energy savings in Italy: Determining the effectiveness of persuasive communication in dwellings", Energy Research & Social Science, vol. 3, pp. 131-142, 2014.
[32] D. Savic, L.V. Lyroudia, and Z. Kapelan, "Smart meters, smart water, smart societies: The iWIDGET project", Procedia Engineering, vol. 89, pp. 1105-1112, 2014.
[33] www.nexans.com (Nexans, "Communiquée de presse," Paris, 31Mars 2014).
[34] M. Aswathi, R. Gandhiraj, and K.P. Soman, "Application and application of smart meter data along with RTL SDR and GNU radio", Procedia Technology, vol. 21, pp. 317-325, 2015.
[35] R. Elangovan, and U.K. Kommuri, "Low loss high isolation NEMS/MEMS switch for high frequency RF applications", Sensors & Transducers, vol. 186, Is. 3, pp. 134-139, March 2015.
[36] J. Gauvin, "Développement de limiteurs de puissance radiofréquence a MEMS-RF", Thèse de Doctorat, Université de Limoges, 14 Décembre 2012.
[37] PIERRON, "Energie électrique – compteur, " Pierron Education, 2008, pp. 7.
[38] M. Brynart et F. Grevisse, "Protection du consommateur Dispositifs and procédures de protection du Consommateur d'électricité," Bruxelles environnement, 2013, pp. 17.
[39] A.C. Santos, J.M.P. Lazoros, C.P. Rodriguez, and E.C. Fernandez, "Performance analysis of a superconducting fault current limiter in a power distribution substation", Electric Power Systems Research, vol. 136, pp. 89-99, 2016.
[40] S. Seo, S.J. Kim, Y.H. Moon, and B. Lee, "A hybdrid superconducting fault current limiter for enhancing transient stability in Korean power systems", Physica C, vol. 494, pp. 331-334, 2013.
[41] J.M. Pina, P. Pereira, A. Pronto, P. Arsenio, and T. Silva, "Modelling and simulation of inductive fault current limiters", Physics Procedia, vol. 36, pp. 1248-1253, 2012.
[42] C.H. Kon, and J. Leveque, "Modélisation et impact de limiteurs supraconducteurs de courants de défaut sur les réseaux électriques", Sciences, Technologiess et Developpement, vol. 14, pp. 1-8, November 2013.
[43] N. SAAD, "Modélisation et simulation du limiteur de courant supraconducteur," Thèse de doctorat, 04 Décembre 2013.
[44] A. Mahmoudian, M. Niasati, and M.A. Khanesar, "Multi objective optimal allocation of fault current limiters in power system", Int. J. Electrical Power and Energy Systems, vol. 85, pp. 1-11, 2017.
[45] A. Morandi, "State of the art of superconducting fault current limiters and their application to the electric power system", Physica C, vol. 484, pp. 242-247, 2013.
[46] S. Lee, J. Yoon, B. Yang, Y. Moon, and B. Lee, "Analysis model development and specification proposal of 154kV SFCL for the application to a live grid in South Korea", Physica C, vol. 504, pp. 148-152, 2014.
[47] D. Tournier, P. Godignon, J. Montserrat, D. Planson, C. Raynaud, J.P. Chante, JF de Plama, and F. Sarrus, "A 4H-SIC high-power density VJFET as controlled cuurent limiter", IEEE Transaction on Industry Applications, vol. 39, no. 5, September 2003.