



# Sawt Al-Jamiaa

**Semi-annual peer-reviewed academic journal**  
Published by «Research & Publication Center»  
Islamic University of Lebanon

- **Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn**  
Prof. Ahmad HOTEIT
- **Renewable Energy Resources Optimal Dispatching in the Context of Smart Grid Towards the Future Power System**  
Dr. Hussein HUSSEIN - Dr. Hussein KHODER



ISSN 2227-0442  
2014 A.D. | 1435 A.H.

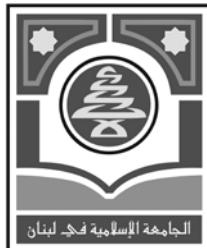
01  
Issue: Six



# صوت الجامعة

# Sawt Al-Jamiaa





## صوت الجامعة Sawt Al-Jamiaa

Semi-annual peer-reviewed academic journal  
Published by «Research & Publication Center»  
Islamic University of Lebanon  
Issue: Six, 2014 A.D. / 1435 A.H.

Chief Editor:

**Dr. Ali Mohsen Kabalan**

**Address:**

**Islamic University of Lebanon**

Research and Publication Center - Administration of «Sawt Al-Jamiaa» Journal

Khaldeh - Main Road

P.O.Box: 30014 - Choueifet - Lebanon

Tel.: +961 5 807711 - 807716 (6 Lines)

Fax: +961 5 807719

[www.iul.com.lb](http://www.iul.com.lb)

[iul@iul.edu.lb](mailto:iul@iul.edu.lb)



# **Index**

Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn <b>Prof. Ahmad HOTEIT .....</b>	<b>7</b>
Renewable Energy Resources Optimal Dispatching in the Context of Smart Grid Towards the Future Power System. <b>Dr.Hussein HUSSEIN - Dr.Hussein KHODER .....</b>	<b>19</b>



# **Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn**

**Prof. Ahmad HOTEIT**

Doyen de la Faculté des Lettres et Sciences Humaines  
Université islamique du Liban

## **I-Préambule**

Le kasrawān, dont les deux Matn actuels (nord et sud) faisaient partie, s'étendait au Sud jusqu'au fleuve de Beyrouth et jusqu'aux montagnes de Sannine et d'el-Kunayssa<sup>(1)</sup>. Ce Kasrawān a été le théâtre entre 691-705/1292-1305 de plusieurs expéditions mamloukes, connues comme «les Expéditions kasrawānaises».

Comme le montrent la plupart des sources, ces expéditions étaient au nombre de trois : la première a eu lieu en 691/1292 et a été menée par l'émir Baidarā, le vice-sultan (Nā‘ib al-saltanā), accompagné des émirs Sunqur al-ashqar, Qarasunqur al-Mansuri et plusieurs grands autres émirs.

Le but principal de cette expédition était de punir les habitants de la région, qui étaient accusés d'aider les Francs contre les Mamlouks, mais ce fut un échec complet<sup>(2)</sup>.

La deuxième expédition a eu lieu en 699/1300. Les Mongols, dirigés par Ghazān, avaient envahi la Syrie (bilād el-Shām) et occupé Damas.

(1) Hitti, Ph., *Histoire du Liban*, traduit de l'anglais par Anis Furaiha, (Beyrouth, 1978), p.398.

(2) A propos de la première expédition, voir: an-Nuwāyīrī, Nihāyat al-Arab, T.32, pp.240-241; al-Jazarī, Hawādith al-Zamān, fol. 62v; Ibn Kathīr, al-Bidāya wan –Nihāya, T.13, pp.327-328; al-Maqrizī, Kitāb as-Sulūk, T.I, partie 2, p.779; Shāleh bin Yaḥya, Tārikh Bayrūt, pp. 24-26.

## *Expéditions mameloukes de kasrawān et Identité des habitants à travers la Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn*

L'armée mamlouke défaite aurait, lors de sa retraite d'Egypte, enduré de nombreux sévices de la part des Kasrawānais: les habitants de la région auraient alors attaqué et pillé les soldats musulmans, leur prenant leurs armes et leurs chevaux, et en massacrant même un certain nombre.

Les Kasrawānais ont été également accusés de corrompre leur religion et leurs croyances, d'infidélité et d'égarement. C'est pourquoi une fois l'ordre rétabli et châtiés ceux qui avaient collaboré avec les Mongols, une nouvelle expédition dans le Kasrawān fut entreprise.

Cette expédition était conduite par le gouverneur de Damas (Nā‘ib el-Shām) Ġamal ed-Din Aqūsh al-Afram, qui se dirigea avec ses troupes vers les « montagnes du Ġurd et du kasrawān ». Les habitants furent alors obligés de payer une lourde contribution qui fut versée au trésor de l'Etat. De plus, leurs territoires et leurs vergers furent donnés en fief (Iqtā‘) aux Tannoukhides<sup>(1)</sup>.

La troisième expédition est celle de 705/1305. Le Gouverneur de Damas al-Afram quitta Damas vers « la région du kasrawān et du Ġurd ». Il encercla la montagne de tous côtés. L'expédition se termina par la destruction de la montagne du kasrawān : les arbres furent coupés, les habitations détruites, une grande partie de la population massacrée, une autre enrôlée dans les troupes de Tripoli (Ġund al-Halqa) ou bien forcée à émigrer vers la région de Djizzine et de la Békā‘<sup>(2)</sup>.

D'autres historiens libanais<sup>(3)</sup>, s'inspirant de *Duwayhī*<sup>(4)</sup> ont proposé une autre version du récit de l'expédition de 705 dans laquelle il est fait mention de la bataille de ‘Ayn Șofar qui s'est déroulée en 707/1307. Lors de cette bataille, Aqūsh al-Afram à la tête de 50000 hommes, a écrasé environ 10000 hommes du kasrawān, dont la plupart étaient druze. L'historien tannoukhide Șāleħ bin yaħya ne parle pas de l'identité confessionnelle de ces Kasrawānais. En revanche, il fait mention de Tannoukhides druzes qui avaient participé à la troisième expédition et qui avaient perdu à la

(1) A propos de la deuxième expédition, voir : Ibn Kathīr, *Ibid.*, T.14, p.12 ; al-Maqrizī, *Ibid.*, pp.902-903 ; Șāleħ, *Ibid.*, p.27 ; Laoust, H., «Remarques sur les expéditions de Kasrawān sous les premiers Mamelouks», bulletin du Musée de Beyrouth, IV, pp.99-101.

(2) A propos de la troisième expédition, voir : Ibn ad-Dawādāri, *Kinz ad-Durar*, T.9, p.40 ; Abu-l-Fidā, *al-Mukhtasar fī Akhbār al-Bashar*, T.4, p.52 ; Ibn Kathīr, *op.cit.*, T.14, p.35 ; al-Maqrizī, *op.cit.*, T.II, Partie 1. pp.14-15 ; Șāleħ, *op.cit.*, pp.27-28, 96 ; Laoust, *op.cit.*, p.103.

(3) Cf. Dibs, Y., *Histoire de la Syrie*, V.6, p.370 ; Hitti, *op.cit.*, p.399 ; Daou, B., *Histoire des Maronites*, III, p. 527.

(4) Duwayhī, E., *Tārikh al-Azminā*, pp.286-289.

bataille de Naybay (Kasrawān) deux de leurs émirs et vingt trois soldats de Ghrab<sup>(1)</sup>.

Nous pouvons, alors, nous demander quelles étaient les communautés kasrawānaises visées par les expéditions mamloukes? Ces communautés avaient-elles pactisé avec les Francs et les Mongols contre les Mamlouks du fait de leur différence religieuse ou confessionnelle? D'autres facteurs politiques étaient-ils à l'origine des expéditions mamloukes contre les kasrawānais?

Autant de questions auxquelles nous essayerons de répondre durant notre intervention.

Les chroniqueurs sont en désaccord sur l'identité des habitants du kasrawān. Nous pouvons distinguer deux tendances principales :

- 1- Selon les uns, leur identité se définit en fonction de la région<sup>(2)</sup>: on trouve dans certaines références des expressions telles que les habitants «des montagnes du kasrawān» ou bien «la montagne des Ĝurdiyyins et des kasrawāniyyins», «les habitants du kasrawān et les habitants de Djizzine», «la montagne du Ĝurd et les habitants du kasrawān », etc...
- 2- Selon les autres, leur identité se définit en fonction de la religion et de la confession<sup>(3)</sup>: on trouve des expressions comme «al-Nuṣairiya, al-Zanniyūn et les autres renégats», «al-Durziya», «al-Ismā’īliya Wal-Nuṣairiya», «al-Rafāḍa», etc...<sup>(4)</sup>

## **II- La Lettre d'Ibn Taimiya**

Ibn taimiya, le Sheik des Hanbalites de Damas, est catégorique au sujet de l'identité des kasrawānais dans sa fameuse lettre au sultan an-

---

(1) Sāleḥ, op.cit., pp.95-96.

(2) Cf. an-Nuwayrī, op.cit., pp.240-242; al-Jazari, op.cit., fol. 62v – 63r ; Ibn Kathīr, op.cit., T. 13, pp.327-328, T.14, p.12; Sāleḥ, op.cit., pp.77-78, Ibn Sbaṭ, *Histoire d'Ibn Sbaṭ*, publié par Omar Abd as-Salām Tadmouri, Tripoli-Liban, 1993. etc...

(3) Cf. Ibn ad-Dawādarī, op.cit., T.9, p.40; Abu-l-Fidā, op.cit., T.4, p.52; Ibn kathīr, op.cit., T.14, p.35; al-Maqrīzī, op.cit. I, partie 3, pp.902-903 et II, partie I, p.16.

(4) Certains historiens libanais (maronites) imposent leur communauté dans le Kasrawān de l'époque mamlouke. Cette dernière était visée, selon eux, par les expéditions ou tout du moins associée à la résistance kasrāwanaise. Cf. Duwayhī, Ibn al-Qilā', Ḥitti, Darian et Daou.

## *Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d’Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn*

Nāṣir Muhammad bin Qalāwūn (683-741/1294-1341)<sup>(1)</sup>, et ce en dépit du désaccord des historiens<sup>(2)</sup>.

Dans cette lettre qui comporte plusieurs développements critiques consacrés à la croyance des kasrawānais, il les accuse d’être des « ennemis de Dieu comme les Tatars et leurs semblables ». Il y a parmi eux une foule d’égare hypocrites qui ont dénigré la tradition (al-Sunnā) et le consensus de la nation (Ijmā’ al-Umma). Ils ont désobéi également aux lois et au pouvoir politique, comme, par exemple, ces gens de Ĝurd de jubeil et du kasrawān combattus par le Sultan. Ce sont, d’après Ibn Taimiya, des Rafaḍa, puisqu’ils déclarent illégitime le Califat des deux Sheikhs, Abu Baker et Omar. Leur secte est identique à celle des habitants de Djizzine et de la région de Jabal ‘Āmel.

La Lettre d’In Taimiya évoque l’Attendu (le Mahdi) des habitants: celui qui ne croit pas en lui est considéré comme infidèle<sup>(3)</sup>.

Ainsi, d’après le Sheikh des Hanbalites, l’identité confessionnelle des kasrawānais est évidente: il y a parmi eux des Ismā‘īliya, des Nuṣairiya, des Ḥākimiya et des Bātiniya. On en conclut, alors, que Ibn Taimiya s’en prend à une seule secte dans le kasrawān: les Shiites<sup>(4)</sup>. Mais, cela n’exclut pas la présence d’autres communautés dans la région du kasrawān: des Druzes (Tayāmina) et des Chrétiens<sup>(5)</sup>.

Ibn Taimiya affirme dans sa lettre que les expéditions kasrawānaises, surtout la dernière (en 705) avaient deux causes principales:

La première est relative à la croyance des kasrawānais: les habitants du kasrawān n’adhéraient aux croyances des sectes Sunnites, sectes que le sultan az-Zahir Baibars avait déclarées officielles (sectes de l’Etat) en 665/1267, en interdisant formellement toute autre secte islamique, et en insistant d’éloigner de toute fonction publique ou religieuse ceux qui n’y croyaient pas<sup>(6)</sup>.

(1) Cette lettre est publiée dans « al-Fikr al-Islāmī » (la Pensée Islamique), 7e année, n°6 (1978), pp.84-88.

(2) Cf. Beydoun, A., *Identité confessionnelle et temps social chez les historiens libanais contemporains*, Beyrouth, 1984, pp.77-127.

(3) Beydoun, Ibid., p.85.

(4) Ibid., p.108.

(5) Salibi, K., Muntalaq *Tārīkh Lubnān*, Beyrouth, 1979, p.138.

(6) Al-Maqrizī, *khuṭaṭ*, T.II, p.161.

*Ibn Hajar al-‘Ascalānī*<sup>(1)</sup> fait mention de l’intolérance et le fanatisme des Mamlouks qui étaient tels qu’une simple accusation, même fausse, de shiisme était suffisante pour calomnier quelqu’un, l’inculper et l’exposer aux pires châtiments.

Ibn Taimiya accuse les kasrawānais d’être des « hérétiques », des « renégats » et des « hypocrites », justifiant, ainsi, dans sa lettre au Sultan, la campagne de 705 qui, pour lui, n’a été décidée qu’après avoir rendu compte de l’état des kasrawānais, réfuté leurs arguments, démontré la fausseté de leurs croyances et l’hypocrisie de leurs Sheiks comme « banū-l-‘Ud », qui les incitaient à combattre les musulmans (les Mamlouks) en confirmant par des missives (Fatwa) la légitimité de leur action<sup>(2)</sup>. Pour cela, le Sheikh de Damas insista dans un long développement sur la nécessité d’entreprendre une politique énergique contre les Kasrawānais<sup>(3)</sup>.

La deuxième raison est la collaboration des kasarwānais avec les Francs et les Mongols: les habitants du kasrawān étaient accusés d’avoir aidé les Francs et les Mongols, surtout à la suite de la défaite des Mamlouks à Wadi el-Khāzindār en 699/1300<sup>(4)</sup>, où ils auraient massacré et pillé la queue de l’armée musulmane et auraient vendu ces soldats aux Francs<sup>(5)</sup>.

### **III- Critique de la Lettre d’Ibn Taimiya**

Notre critique repose sur un postulat qui peut se résumer de la façon suivante:

Le pouvoir politique au Moyen Age, et même à l’époque contemporaine, détermine, d’une manière générale, ses relations avec ses sujets en fonction de la soumission ou de l’opposition de ces derniers, et quelle que soit leur croyance religieuse ou confessionnelle. Mais, cela n’exclut pas l’existence, aux marges, de facteurs religieux et confessionnels qui émergent de temps à autre, selon les circonstances.

La population kasrawānaise qui vivait dans des montagnes abruptes, difficiles à atteindre et compartimentées par des agents climatiques, ne

(1) *Ibn Hajar al-‘Ascalānī, ad-Durar al-Kāmina fī Ayān al-Mā‘ al thāmina*, Beyrouth, T.2, p.46.

(2) Al-Fikr al-Islāmī, op.cit., p.85.

(3) Ibid., p.86; al-karmī, *al-kawākib ad-Durrīya*, Le Caire, 1927, p.97.

(4) Ibn ad-Dawādārī, op.cit., t.9, pp.15-18.

(5) Al-Fikr al-Islāmī, op.cit., p.85.

## *Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn*

connaissait pas les lois de l'Etat et n'était soumise à aucune armée<sup>(1)</sup>. Elle est restée, jusqu'en 705/1305, loin de la domination des gouvernements mamlouks de Damas et semble avoir échappé au pouvoir des Francs<sup>(2)</sup>.

En 690/1291, quand les Mamlouks affermirent leur pouvoir en Syrie en mettant fin à la présence des Francs<sup>(3)</sup>, le Sultanat mamlouk décida d'organiser des expéditions vers la région du kasrawān peuplée de minorités islamiques dissidentes (à majorité shiites) auxquelles se seraient jointes certaines communautés chrétiennes<sup>(4)</sup>, pour les maîtriser et les soumettre. On en conclut, alors, que le but de la campagne de 691 était, en premier lieu, d'obtenir la soumission politique des kasrawānais, désignés comme « rebelles » dans les sources arabes.

Dès son arrivée et celle de ses troupes dans la région, l'émir Baidarā, chef de campagne, entreprit des négociations avec les notables du kasrawān et les incita en les menaçant d'utiliser la force à déclarer leur soumission à l'Etat Mamlouk. Il leur promit, afin de gagner leur confiance, de libérer certains de leur dirigeants retenus à Damas<sup>(5)</sup>. Cette attitude a alerté certains émirs, compagnons de Baidarā, qui l'ont dénoncé au Sultan, l'accusant de se laisser corrompre par les kasrawānais<sup>(6)</sup>.

De même, à la suite de la deuxième expédition, en 699, dirigée par al-Afram, la protection était accordée aux kasrawānais, à condition qu'ils aient payé au trésor de l'Etat 100 000 Dirhams et qu'ils aient déclaré leur obéissance<sup>(7)</sup>.

Les chroniques font mention d'un envoi par Damas de deux groupes successifs de missionnaires pour négocier avec les kasrawānais à la veille de la troisième campagne. Le premier groupe était dirigé par Naqib al-Ashraf Zaïn Eddin bin 'Adnān, le second par le Sheikh Ibn Taimiya. Le but de ces deux missions était de persuader les kasrawānais de la nécessité d'obéir aux Tannoukhides, les nouveaux chefs féodaux de la région<sup>(8)</sup>.

(1) Lammens, H., *La Syrie, précis historique*, Beyrouth 1921, vol II., pp.12-13 ; Laoust, op.cit., p.102.

(2) Salibi, op.cit., pp.132-133.

(3) Hoteit, A., *Histoire du Liban médiéval*, Beyrouth, 1986, p.55-103.

(4) Salibi, K., et autres, *Lubnān fī tārīkhihī wa turāthihī*, Beyrouth, 1993, p.212.

(5) An-Nuwāyri, op.cit., p. 41; al-Jazarī, op.cit., fol. 62 v; Sāleḥ, op.cit., pp.24-25.

(6) An-nuwayri, p.41; al-Jazarī, fol.63r; Sāleḥ, pp.24-25.

(7) Ibn ad-Dawādārī, op.cit., p.40; al-Maqrizī, *as-Sulūk*, I, partie 3, pp.902-903.

(8) Ibn kathīr, op.cit., T.14, p.35; al-Maqrizī, *Ibid.*, II, partie 1. p.12; Sāleḥ, op.cit., p.27; Duwayhī, op.cit., p.286.

Après l'échec de ces deux missions, l'émir al-Afram attaqua le kasrawān aidé des gouverneurs de Tripoli et de Ṣafad, les émirs de Gharb et d'Ibn Taimiya qui écrivit dans toute la Syrie pour inciter les gens à la lutte et pour démontrer de la légitimité de la campagne. Le rôle de ce dernier dans cette campagne, comme dans celle qui la précédait (699), fut celui d'un légiste et d'un propagandiste officiel<sup>(1)</sup>.

Il en résulte que la « rébellion fut vite matée, et la répression fut terrible, suivie de massacres, de destructions et de déportations »<sup>(2)</sup>.

La participation des émirs druzes de Gharb aux expéditions de Kasrawān, bien qu'une communauté druze y soit installée - communauté dont la présence est directement signalée par des chroniqueurs : « les Druzes », « al-Durziya »<sup>(3)</sup>, ou indirectement par leur appartenance régionale : « al-Tayāmina », habitants de la vallée de Taïm ; ou religieuse : « Hākimīya »<sup>(4)</sup>, relatif au Fatimide al-hākim- confirme le fait que les mobiles de ces expéditions étaient plutôt politiques que religieuses ou confessionnels<sup>(5)</sup>.

Dans sa lettre, Ibn Taimiya donnait comme prétexte l'aide que les habitants de kasrawān auraient accordée aux Francs et aux Mongols pour justifier les expéditions menées contre la région. Mais, ces prétextes n'étaient pas vraiment fondés puisque les circonstances de l'époque n'étaient pas prises en considération : en Syrie, les Mamlouks luttaient alors contre les Croisés, d'une part, et contre les Mongols, d'autre part. Le climat orageux qui s'abattit sur le pays à cette époque se répercutait sur l'attitude des communautés indigènes. Ces dernières ne savaient pas, alors, quelle position adopter et à qui s'allier. Tel était également le cas des émirs de Gharb, les Tannoukhides.

Les chroniqueurs sont unanimes quant aux hésitations des Tannoukhides dans leurs relations avec les Ayyubides, les Mamlouks et les seigneurs Francs de Beyrouth. Ils entretenaient avec ces derniers des rapports d'amitié, ce qui amena le sultan ayyubide an-Nāṣir Yussif, gouverneur d'Alep et de Damas, à organiser en 653/1255, une campagne contre eux pour les châtier<sup>(6)</sup>.

(1) al-Karmī, op.cit., p.97; Laoust. H., *Essai sur les doctrines sociales et politiques de Taki – d- Din Ahmad B.Taimiya*, Le Caire, 1939, p.124.

(2) Ismail, A., *le Liban, Histoire d'un peuple*, Beyrouth, 1965, p.75.

(3) Cf. Ibn ad-Duwādārī et al-Maqrīzī.

(4) Cf. Ibn Kathīr et Duwayḥī.

(5) Laoust, H., *Remarques sur les expéditions de Kasrawān*, pp. 111-112.

(6) Sāleḥ, pp.58-59.

## *Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d’Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn*

De même, la politique d'équilibrisme pratiquée par les Tannoukhides pendant la guerre entre les Mongols et les Mamlouks, à la veille de la bataille d'Ayn Djälüt<sup>(1)</sup>, en 658/1260, avait des conséquences négatives : pendant cette bataille, les Tannoukhides se repartirent impartiallement entre les deux camps ennemis pour être assurés de se voir représenter avec le parti vainqueur. Les Mongols ayant été mis en déroute, les Tannoukhides qui les avaient rejoints n'hésitèrent pas à se tourner contre leurs anciens compagnons d'armes<sup>(2)</sup>.

Le sultan az-Zahir Baibars (658-679/1260-1277), qui redoutait leur revirement, emprisonna trois de leurs grands émirs, en déclarant ne les libérer qu'après le départ des Francs. Après la mort de Baibars, ces émirs furent remis en liberté par son fils, le Sultan al-Saïd Barakā (679-678/1277-1279). Cependant, le Sultan al-Manṣur Qalāwūn (678-689/1279-1280) confisqua leurs fiefs et les surveilla de près. En 690/1291, le Sultan al-Ashraf Khalil (689-693/1290-1293) leur rendit leurs charges et leur donna des fiefs hors de leur pays, après les avoir engagés dans le service militaire mamlouk<sup>(3)</sup>. Leurs fiefs de Gharb leur furent rendus à la demande que leur chef l'émir Nāṣir-ed-Din al-Hussein (d.751/1350) fit auprès du Sultan an-Nāṣir Muhammad bin Qalāwūn<sup>(4)</sup>.

Ajoutons que certains émirs mamlouks avaient eux aussi, aidé les Mongols contre leur propre Sultanat, tels l'émir Sunqur al-Ashqar et l'émir Azdamur el-Hāj qui avaient invité les Mongols à occuper le pays<sup>(5)</sup>.

Le passage de la lettre d'Ibn Taimiya sur les agressions que les kasrawānais avaient exercées contre les troupes mamloukes en 699 était aussi destiné à justifier les expéditions kasrawānaises<sup>(6)</sup>. Mais, même si ces accusations étaient fondées, elles ne peuvent pas être mises sur le compte des pillages qui accompagnaient, en temps normal, toute défaite militaire, et non sur le compte d'une éventuelle collaboration ou d'un pacte avec les Francs et les Mongols.

En réalité, l'existence d'une minorité rebelle dans une position

(1) Lewis, B., “Ayn Djälüt”, El2, I, pp. 810-811.

(2) Sāleḥ, pp.59-60.

(3) Hoteit, et autres, *Lubnān fi Tārīkhīhī*, p.193.

(4) Sāleḥ, pp. 71-72.

(5) Ibn Abdel-Zāhir, *Tashrīf al-Aiyām wal-Usūr fī Ṣīrat al-Malik al-Manṣur*, Le Caire, 1961, p.76 ; Ibn Kathīr, op.cit., T.13, pp.290-292.

(6) Al-Fikr al-Islāmī, op.cit., p.85.

géographique stratégique, aussi importante que le kasrawān, était d'autant plus redoutable que l'on vivait toujours dans la crainte, bien justifiée d'un retour des flottes franques et le péril mongol n'était pas écarté.

La suppression de cette dissidence shiite était nécessaire à la sécurité de l'Etat Mamlouk. « Il nous paraît, écrit *Laoust*<sup>(1)</sup>, inexact de chercher à présenter ces campagnes comme une manifestation du fanatisme sunnite contre les chiites, mais beaucoup plus judicieux d'y voir avant tout une importante opération de police ». Plusieurs arguments confirment cette opinion :

- 1- Des Druzes Tannoukhides ont participé à ces expéditions malgré la présence de Druzes parmi la population kasrawānaise.
- 2- Azdamur, le gouverneur de Tripoli, après la défaite des kasrawānais, a engagé certains de ces montagnards dans ses troupes en les salariant et leur faisant verser une solde régulière par le trésor de l'Etat<sup>(2)</sup>.
- 3- De nombreux Nuṣairis ont été engagés dans des fonctions militaires et civiles par les Mamlouks<sup>(3)</sup>.

## **IV- Conséquences des expéditions kasrawānaises**

Les expéditions mamloukes sur le kasrawān ont causé des bouleversements tant au niveau social que politique. Elles ont entraîné un dépeuplement de la région. Les habitants qui ont survécu aux événements se trouvaient obligés de se retirer vers d'autres régions plus calmes de Syrie.

Les Shiites ont émigré vers la Békā‘, Djizzine et jabal ‘Āmel. Ils ont dissimulé leur véritable croyance confessionnelle en affichant leur adhésion à la secte sunnite shafite (Taqiya). Une fois, la sécurité rétablie, certains d'entre eux retournèrent dans les régions les plus escarpées de la montagne du kasrawān, évitant la côte du fait de la présence des Turcomans<sup>(4)</sup>.

Quant aux Druzes, ils s'installèrent dans la région montagnarde du

---

(1) Laoust, *Remarques*, p.111.

(2) Ṣāleḥ, *op.cit.*, p.28.

(3) Dussaud, R., *Histoire et religion des Noṣairis*, p.29 ; Laoust, *op.cit.*, p.111.

(4) Ṣalibī et autres, *Lubnān*, p.221.

Shouf, tandis que les Nuṣairis se dirigèrent vers le Nord où ils se fixèrent à ‘Akkār. Certains Nuṣairis se convertirent au Sunnisme<sup>(1)</sup>.

Les chrétiens de Liban Nord, en particulier, les Maronites, qui n’avaient aucune raison de s’associer aux rebelles - on ne possède pas d’ailleurs encore de preuves incontestables de leur participation à la rébellion- profitèrent du dépeuplement du kasrawān pour combler le vide dans cette région sans aucune opposition de la part des Mamlouks qui, d’après *Adel Ismail*<sup>(2)</sup> « préféraient des chrétiens neutres et paisibles aux musulmans dissidents, toujours prêts à la rébellion ».

Plus tard, dès la fin du 15<sup>e</sup> siècle, et peut-être au début du 16<sup>e</sup> siècle, les Maronites commencèrent à s’installer dans le kasrawān et le Jubeil, profitant des conflits entre Banū Tannoukh Druzes et Banū ‘Assāf, sunnites d’origine Turcomane, pour accomplir leur domination progressive de kasrawān<sup>(3)</sup>.

Pour assurer la défense du littoral Libano-Syrien contre les incursions des Francs, les terrains kasrawānais furent donnés en fief (*Iqtā‘*) à quelques émirs mamlouks ; plus tard, on les leur enleva pour les donner à Banū ‘Assaf qui furent chargés de défendre la région côtière entre Beyrouth et Tripoli<sup>(4)</sup>. A cette communauté, on ajoutera Banū Saifa, sunnite d’origine kurde<sup>(5)</sup>, qui ont défendu la partie Nord du Liban (Tripoli et ‘Akkār). Elle y est demeurée jusqu’à sa défaite contre l’Emir Fakhr ed-Din II (1572-1635).

Les émirs tannoukhides furent chargés de la défense de Beyrouth et de la côte s’étendant jusqu’à Saïda<sup>(6)</sup>.

Enfin, on pourrait dire que les transformations de la structure sociale et religieuse de la population libanaise, causées par les expéditions mamloukes de kasrawān, ont dessiné les grands traits de la répartition démographique du Liban dont certains vestiges perdurent encore de nos jours.

---

(1) Ismail, *Le Liban*, p.75.

(2) *Ibid.*, p.75.

(3) Sāleḥ, op.cit., pp.178-179; Daou, op.cit., pp. 560-561.

(4) Sāleḥ, *Ibid.*, p.37; Poliak, *La féodalité*, pp. 37-38.

(5) Poliak, *Ibid.*, p.37 et 45.

(6) Lammens, op.cit. p.17. A propos de cette mission de défense, voir : Makārem, S. et autres, *Lubnān*, pp. 248-250.

## Bibliographie

- Ibn Abdel -Zāhir, Tashrif al-Ayyām wal ‘Uṣur fi Sirāt al-Malik al-Mansūr, publié par Murad Kamil, Le Caire, 1961.
- Ibn ad-Dawādari, Kinz ad-Durar wa Jama’ al-Ghurar, T. 9, Publié par R. Remer, Le Caire, 1960.
- Ibn Ḥajar al - Ascalāni, ad -Durar al-Kāmina fi Ayān al -Māa‘ al-Thāmina, Beyrouth ( sans date d'édition).
- Ibn Kathīr, al-Bidāya wan-Nihāya fi- Tārikh, Beyrouth, 1966.
- Ibn Sbāṭ, Histoire d'Ibn Sbāṭ, publié par Omar Abd as-Salām Tadmuri, Tripoli (Liban) , 1993.
- Ibn Taimiya, A., La Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Kalawōn, in **Revue al -Fikr al- Islami**, 7ème année, n.6, Beyrouth,1978.
- Abu-l-Fidā, al-Mukhtaṣar fi Akhbār al-Bashar, Beyrouth (sans date d'édition).
- Beydoun, A., Identité confessionnelle et temps social chez les Historiens Libanais Contemporains, Beyrouth, 1984.
- Daou, B., Histoire des Maronites, Beyrouth, 1977.
- Dibs, Y., Histoire de la Syrie, Beyrouth, 1902.
- Duwayhi, E., Tārikh al- Azmina ( 1095- 1699), Publié par F. Tutel, in **Revue de l'Orient**, n. 44, Beyrouth, 1950.
- Hitti, Ph., Tarikh Lubnān, Traduit par A. Furaiha, Beyrouth, 1978.
- Hoteit, A., Histoire du Liban médiéval, Beyrouth, 1986.
- Ismail, A., Histoire d'un peuple, Beyrouth, 1965.
- al-Jazari, Hawādith al-Zamān wa Anbaouhā wa Wafawāt al-Akābir min Ayān Abnāiha, Manuscrit de Kubruly, n. 1037.
- al- Karmi, M., al-Kawākib ad-Durriya fi Manākib as-Shaikh Ahmad bin Taimiya, Le Caire, 1927.

*Expéditions mamloukes de kasrawān et Identité des habitants à travers la Lettre d'Ibn Taimiya au Sultan an-Nāṣir Muhammad Bin Qalāwūn*

- Laoust, H. :
  - \* Essai sur les doctrines sociales et politiques de Taki ed-Din Ahmad B. Taimiya, Le Caire, 1939.
  - \* “Remarques sur les expéditions de Kasrawān sous les premiers Mamlouks”, **Bulletin du Musée de Beyrouth**, T. IV, 1940.
- Lammens, H., La Syrie, précis historique, Beyrouth, 1921.
- Makarem ,S. et autres, Lubnān fi Tārikhihi wa turāthihi, Beyrouth, 1993.
- Makki, M.A., Le Liban de la conquête arabe à la conquête ottomane, Beyrouth, 1976.
- al-Maqrizī :
  - \* Kitāb as-Sulōk Lima‘rifat Dūwal al-Mulūk, T.1-3, Publié par Mohammad Muṣṭafa Ziadeh, Le Caire, 1958.
  - \* al-Mawāiẓ wal-I’tibār fi zikr al-Khuṭāṭ wal-Āthār (al-Khuṭāṭ al-Maqriziyya), Le Caire, 1270h.
- an-Nuwari, Nihāyat al-Arab fi Funōn al-Adab, T. 32, Le Caire, 1995.
- Poliak, A.N., La féodalité en Egypte , Syrie, Palestine, et Liban, Beyrouth, 1948.
- Şaleh bin Yahya, Tārikh Bayrōt, Publié par F. Hors et K. al-Şalibi, Beyrouth, 1967.
- Şalibi, K., Muntalaq Tārikh Lubnān, Beyrouth, 1979.
- Şalibi, K. et autres, Lubnān fi Tārikhihi wa Turāthihi, Beyrouth, 1993.

# **Renewable Energy Resources Optimal Dispatching in the Context of Smart Grid Towards the Future Power System.**

**Dr.Hussein HUSSEIN**

Lebanese university  
Faculty of engineering- Branch 1.

**Dr.Hussein KHODER**

kassim university  
Faculty of engineering

## **Abstract**

To optimally manage the operation of a microgrid Laboratory, the scheduling of generation units taking into account all technical constraints is essentially an optimization problem. In this paper the optimal operation scheduling of small power systems which consists of a wind turbine, a solar unit, a fuel cell and two storage batteries banks is formulated as an optimization problem. Due to the type of variable involved, this problem is stated a Mixed–Integer Quadratic Programming model (MIQP) containing two types of variables, integer and continuous corresponding to decision that must be taken and power output respectively, while satisfying all technical constraints. This model is solved by a deterministic optimization technique CPLEX-based implemented in General Algebraic Modeling Systems (GAMS). This algorithm has been used as Virtual Power Producer (VPP) software. A VPP can operate the generation units, assuring a global functioning of all equipments efficiently, taking into account the maintenance, operation and the generation measurement and control considering all involved costs. The VPP software acts similarly to a simple personal computers networks to link together seldom-used equipments standby and

all load allowing its optimal control by a mini Supervisory Control and Data Acquisition (SCADA) system and Programmable Logic Controllers (PLC) devices. The application of this methodology to a real case study of the laboratory equipments, demonstrates the effectiveness of this method to solve the optimal dispatch and online control of the microgrid towards intelligent one that is the Smart–Grid, encouraging the extension of the application of this methodology to a large power system.

*Keywords:* Microgrids, photovoltaic and solar panel, wind energy, Smart–Grid, Virtual power producer, Scheduling, Optimization.

## 1- Introduction

Distributed Energy Resources (DER) have been receiving a great attention as alternatives to centralized energy resources [1]. As the DER systems penetration increases into distribution and transmission networks, their interconnection is being developed to be grid-like, also known as microgrid, which are defined as a cluster of distributed generation units and loads that can operate as grid connected or autonomous (islanded) mode [2].

The European Community indeed is promoting different projects initiatives from universities to European industries to support this research [3]. Specifically, European directive 20/20/20 aligns with the interest in these systems which is increased by the possibility of implementing them on large scale renewable energy sources to limit greenhouse gas emissions and also reducing the transmission and distribution active power losses also by year 2020. In a power system it is important to estimate the load curve based on statistical, analytical or technological models. Also generation units and storage systems must be modeled. In this paper, the load curve has been forecasted for 672 periods 15 min each. Likewise, the generators have been set with technical constraints arrangement based on minimal/maximal capacity limit, fuel amount consumption and speedup ratio. Two battery banks have been used as storage system in the micro grid laboratory.

The coordination of all these distributed generating units and their loads is a challenging issue that demands distributed intelligence infrastructure which is referred to Smart grids [4]. In literature, few articles proposed operational solutions for micro grids controlled by Virtual Power Producer

(VPP) making the grid intelligent, self-adaptive, self-balanced, self-monitored and therefore, operating as a Smart grid. In Refs. [5, 6] a linear programming model for cost minimization corresponding to unit commitment of generating units and storage system within a micro grid has been developed. Likewise, in [7] a new formulation of unit commitment scheduling problem based on benders decomposition optimization technique is presented.

This method appears to be suitable for solving a complex scheduling of a large micro grid that is not the case under study. In Ref. [8] an optimal scheduling of a renewable micro grid in an isolated load area has been formulated for a period of one day (24 h) and 1 h time interval each. Likewise, in [9] a scheduling of

DER in an isolated grid has been proposed where the optimization problem has been solved firstly by Branch and Bound technique and then used by an artificial neural network (ANN) to better manage the DER. In all these references, the optimal scheduling is formulated as MILP without taking into account minimization of active power losses.

This paper deals with detailed formulation of a micro grid working not only under isolated operation but also connected to an LV power distribution grid. The problem is formulated as a Mixed- Integer Quadratic Programming (MIQP) model, where the active power losses, distribution network constraints and the buses distribution network voltages have been taken into account.

The proposed optimization algorithm has been used as a VPP for controlling the developed micro grid laboratory. The VPP software acts similarly to a simple personal computers networks to link together seldom-used equipment standby and all load allowing its optimal control by a mini Supervisory Control and Data Acquisition (SCADA) system and Programmable Logic Controllers (PLC) devices.

The optimization problem is managed each 15 min time interval for one week (672 periods) by the micro grid central controller located at one of the generation buses. The proposed problem is solved by a deterministic optimization technique using CPLEX [10], implemented in General Algebraic Modeling Systems (GAMS) [11].

## **2- VPP software based on laboratory**

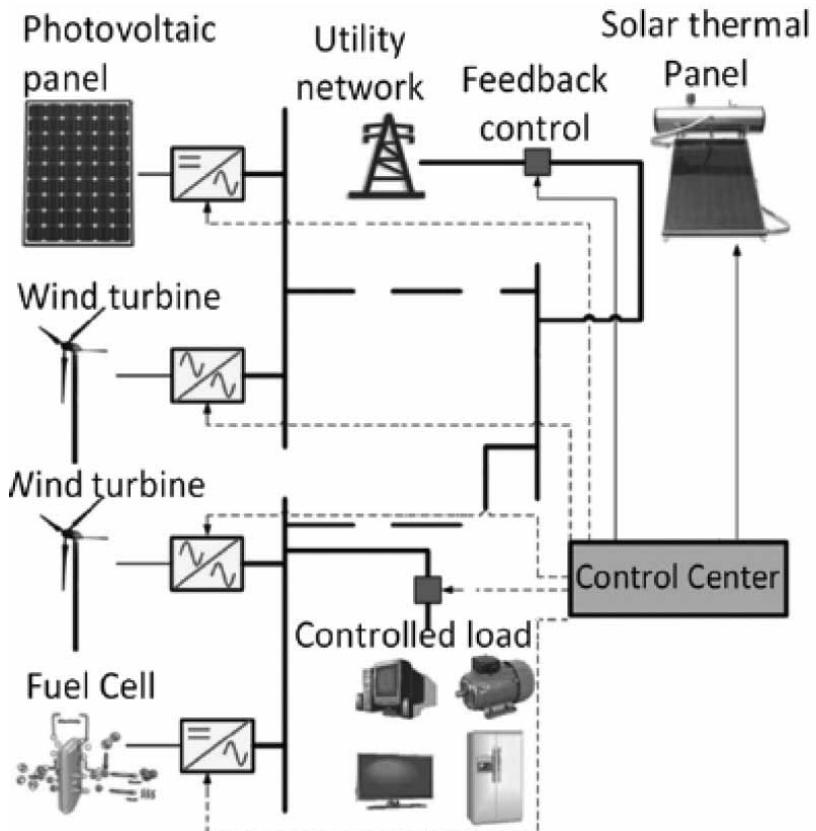
The main idea is to make the optimal operation of the laboratory equipment by a virtual way using Internet with available protocols.

To deal with this issue it is necessary to formulate a detailed optimization model for minimizing all involved marginal cost subject to technical constraints. The proposed MIQP optimization model has been used in remote SCADA Dispatch Workstation.

The laboratory implements a mini Supervisory Control and Data Acquisition (SCADA), which acts as the communication gateway for local and remote operators, and the MOVICO ll [12] software that can be integrated with MATLAB programming language [13]. MATLAB can also be integrated with the General Algebraic Modeling System (GAMS). The GAMS is specifically designed for modeling linear, non-linear and mixed-integer optimization problems.

The database is performed in Excel, and finally this data is sent to the GAMS coded model for running the adequate solvers. The obtained results from GAMS systems are sent as a file which would be read by MOVICON\_ll system. This system is used as programming language to communicate the decision to interruption devices equipped by PLC devices. It is also used for limiting all equipment and loads to optimal obtained values. The mini-SCADA has a connection to Internet provider via Modem. Authors think that future developments of this work should be performed in order to emigrate to the application of IP-Phones which allow users to widely control the equipment while taking the Electricity market dynamic prices into account. On the context of this paper, the scheduling of DER controlled by the above mentioned SCADA system leads to the concept of VPP. VPPs are the software that controls the multi-technology and multisite heterogeneous entities as shown in Fig.1. At the same time, VPPs are able to achieve a more robust generation profile taking into account all involved cost and satisfying all technical constraints, raising the value of non-dispatched generation technologies [14].

The main feature of the proposed VPP is its ability to create any number of virtual sites from the total resource set available controlling all generation equipment and loads. This allows power producers to select the kind of optimal operation generating units and the exact amount of dispatched power necessary to feed all loads.



**Fig. 1. Virtual microgrid control**

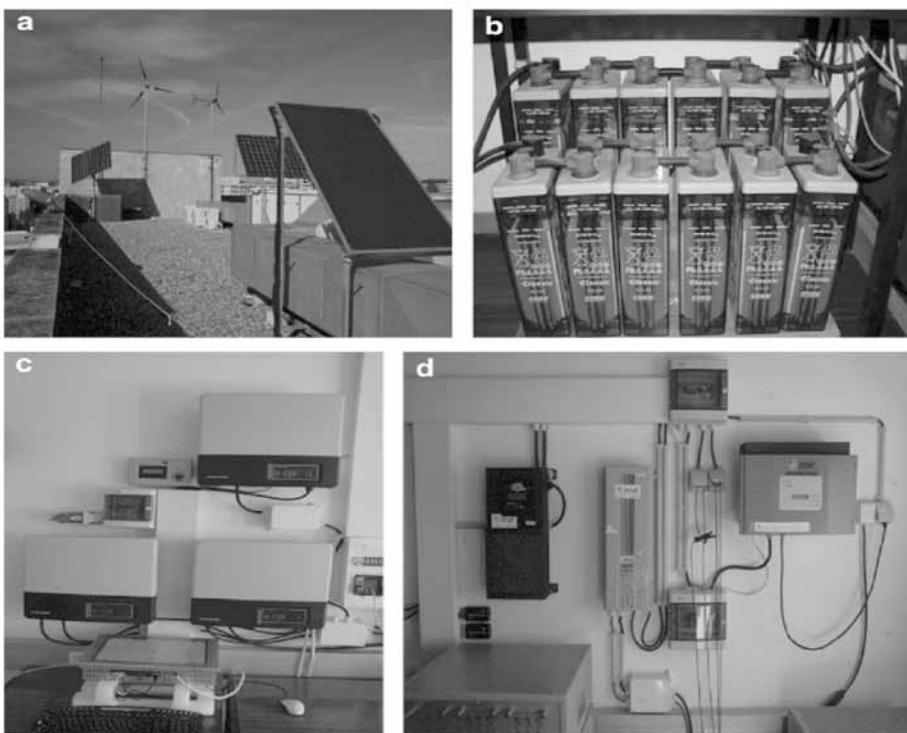
The VPP objective is to combine the generation of aggregated producers to sell as much as possible of programmed energy in the market. In this sense, it remunerates the producers and gets not only its own profits, but also the costumer's satisfaction. When VPP is managing isolated grids the most important objective is to deliver the necessary energy to assure the optimal function of loads connected into isolated system. Therefore, it is necessary to manage the reserves and operation of controllable generation units (fuel cells and micro turbines).

In the laboratory application, the VPP operates as a Distributed Energy Management System (DEMS). The system may be sophisticatedly elaborated to display the present status of systems on each operation point, generates prognoses and quotations, and controls electric power generation of each unit according to its type as scheduled by the optimization model. Us-

ing installation status information, such as electric power output, and combining it with electricity market price forecasts, DEMS generates a forecast that also takes into account the online dynamic prices and the total power available for sale. Even weather data is factored into the energy management system to provide a forecast of the power available from distributed generation sources with fluctuating availability, such as wind and sunshine.

### **3- Micro grid laboratory equipment**

The micro grid laboratory consists of a small renewable energy system that integrates a wind turbine, photovoltaic panels, a - fuel cell unit, a PLC and other equipment. The test system is implemented at the roof of a building and other equipment is installed on its interior. This developed micro grid laboratory can be appreciated in Fig. 2.



**Fig. 2. Elements of the intelligent renewable microgrid laboratory, (a) solar panels and wind turbines installed, (b) batteries implemented, (c) inverters, (d) converter and regulator.**

## **4- Problem formulation**

The optimal generation loads scheduling problem is formulated as a MIQP model. It has been developed aiming to find the optimal scheduling of the distributed renewable energy units, storage systems and its corresponding operation strategies during a specified time period.

This model is very flexible due to the inclusion of all costs: investment cost, operating cost, maintenance and running cost among others. The economic dispatch problem is one of the fundamental issues in power systems operation and scheduling. Essentially, it can be stated as an optimization problem aiming to minimize the total generation cost, while satisfying all technical constraints formulated for micro grid system.

Decision variable are composed of integer variables and power output by continuous ones. The integer variables express the decision of equipment, the one off status operation of distributed generation units, as well as the existence of energy storage devices. The continuous variables express the input and output power flow of the systems components.

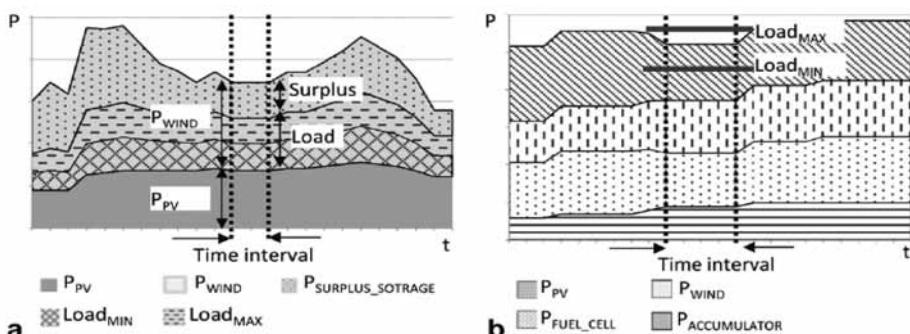
The problem formulation of the laboratory system is developed as a VPP operation in an isolated grid. However, it may be connected to the distribution network.

In order to determine the optimal generated power by wind, photovoltaic, fuel cell units and the storage batteries banks charging and discharging, the optimal operation is formulated taking into account that the wind power generation is intermittent and strongly depends on the weather conditions, as well as the photovoltaic generation. However, both generation profiles can be estimated or calculated for the considered time period. In this case is for a period of one week each 15 min time interval (672 time periods). Wind energy is dispatched during the mentioned time period due to the low generation cost in Euro/kWh. Likewise, it is considered that the fuel cell has limited power output for a long time, but the total generated energy is determined by the amount of the hydrogen fuel [15]. The storage discharging has been considered to be limited for a maximal power discharging capacity and existing storage energy; in this case, two battery banks have been considered independently. As a consideration to keep system balance, the VPP can manage a minimum energy reserve in function of forecasted load and which can be achieved by means of storage system and fuel cell units.

The objective is to carry out an optimal dispatch taking into account all the aforementioned considerations. The results are expected to follow priorities according to the generation price types. The first considered generation due to its price is the wind; the second is photovoltaic and the third is the Fuel cell (if it is necessary). The surplus of energy is used for charging the storage battery banks systems. The different units have different costs, as well. The storage energy has been limited; the hydrogen based fuel cells have expensive cost and limited capacity.

The problem constraints have been elaborated considering the five different operation modes, ( I ) a surplus of energy can be designated to storage systems, as shown in Fig. 3(a), (ii) discharge of batteries banks due to insufficient primary power generation, (iii) batteries banks and fuel cell come into operation due to lack of primary power generation (no wind blooming and/or sunshine irradiation) as shown in Fig. 3(b), (iv) only fuel cell comes into operation in case of lack of energy storage, (v) shed of load to maintain balance between generation and load in case of insufficient energy generation.

In case of all loads and storage systems have been satisfied, then an excess on power generation may exist. In this case, this exceeding power may be injected to the main grid (the distribution network) with a predetermined accorded cost per kWh.



**Fig. 3 Problem constraints considering operation modes, (a) surplus of primary energy, (b) storage and fuel cell are in operation.**

The main propose is to find the minimal marginal cost for a 672 periods, each 15 min during a week schedule. However, it can be extended to a month or a year. In this case, the proposed methodology is still valid.

The objective function is similar to [8], but the principal difference is the cost of the active power losses occurred into distribution network lines. This function is stated as follows:

$$\text{Min } f = \sum_{i=1}^{Nd} \sum_{t=1}^n C_w(t) \cdot P_w(t) + C_{Pv}(t) \cdot P_{Pv}(t) + C_{Fc}(t) \cdot P_{Fc}(t) + \\ C_{Sd}(t) \cdot P_{Sd}(t) + C_{Sd_2}(t) \cdot P_{Sd_2}(t) - C_{Sc}(t) \cdot P_{Sc}(t) - C_{Sc_2}(t) \cdot P_{Sc_2}(t) + \\ C_{ENS}(t) \cdot P_{ENS}(t) - C_{EX}(t) \cdot P_{EX}(t) - \sum_{i=1}^{Nd} \sum_{t=1}^n C_i(t) \cdot \Delta P_i^2(t) \quad (1)$$

Subjected to the following technical constraints:

While minimizing the total marginal generation cost, the total generation should be equal to the total system demand plus the distribution network active power losses.

First Kirchhoff Law or Power Balance on the nodes of the network

$$\sum_{i=1}^{Nd} \sum_{t=1}^n P_w(t) + P_v(t) + P_{Fc}(t) + P_{Sd}(t) + P_{Sd_2}(t) + P_{ENS}(t) - \\ P_{EX}(t) - P_{Sc}(t) - P_{Sc_2}(t) - Load(t) - \Delta P_i(t) = 0 \quad (2) \\ t = 1, \dots, n; \quad i = 1, \dots, nd$$

The wind power generation output in each time interval of the unit should be between its minimum and maximum technical limits. The minimum limit is calculated or estimated for avoiding damage and harm of the wind generator form mechanical standpoint. The maximum limit the power produced by wind turbine is determinate by local wind speed forecasting and equipments characteristics.

Wind power generation limits in each time interval “*t*”

$$P_{Wmin}(t) \leq P_w(t) \leq P_{Wmax}(t); \quad t = 1, \dots, n \quad (3)$$

PV is assumed to produce electricity in proportion to the capacity of the installed system and the amount of solar irradiation. Thus, the Photovoltaic power generation output of the unit should be between its minimum and maximum limits provided by the manufacturer on the considered time interval. These limits are assumed to be calculated in advance according to a certain solar irradiation on lieu where the equipments are installed.

Photovoltaic power generation limits in each time interval “ $t$ ”

$$0 \leq P_V(t) \leq P_{Vmax}(t); \quad t = 1, \dots, n \quad (4)$$

The Fuel Cell power generation output should be minor or equal to its maximal limit provided by the manufacturer on the considered time interval. This generation output should also be positive.

Fuel Cell power limits in each time interval “ $t$ ”

$$0 \leq P_{Fc}(t) \leq P_{Fcmax}(t); \quad t = 1, \dots, n \quad (5)$$

Regarding to the storage systems, there are two batteries banks. Each battery bank is formed by 12 units connected in series forming a unique batteries bank with 24 V and 190 Ah. For simplicity, each batteries bank is treated as one battery. In this paper, these storage systems are considered independently. However, they have equal characteristics. Therefore, each system has its proper constraints.

For the storage system 1 or batteries bank 1 or simply battery 1:

Storage battery 1 limits in each time interval “ $t$ ”

$$0 \leq P_S(t) \leq P_{Smax}(t); \quad t = 1, \dots, n \quad (6)$$

Storage battery 1 maximal discharge limits in each time interval “ $t$ ”

$$P_{Sd}(t) \leq P_{Sdinitial}(1) \cdot X(t); \quad t = 1, \dots, n; \quad X = 0 \text{ or } 1 \quad (7)$$

Storage battery 1 maximal charge limits in each time interval “ $t$ ”

$$P_{Sc}(t) \leq P_{Scmax}(t) \cdot Y(t); \quad t = 1, \dots, n; \quad Y = 0 \text{ or } 1 \quad (8)$$

The battery 1 cannot charge and discharge at the same time in each time interval “ $t$ ”

$$X(t) + Y(t) \leq 1; \quad t = 1, \dots, n; \quad X, Y = 0 \text{ or } 1 \quad (9)$$

Storage battery 1 maximal discharge limits in each time interval “ $t$ ” considering the battery state storage in period  $t-1$

$$P_{Sd}(t) - P_S(t-1) \leq 0; \quad t > 1, \dots, n \quad (10)$$

Storage battery maximal charge limits in each period “ $t$ ” considering the battery state storage in time interval  $t-1$

$$P_{Sc}(t) + P_S(t-1) \leq P_{Smax}(t); \quad t = 1, \dots, n \quad (11)$$

Balance state of the battery on the initial state

$$P_S(t) = P_{s_0} - P_{Sd}(t) + P_{Sc}(t); \quad t = 1 \quad (12)$$

Balance state of the battery 1 in each time interval “ $t$ ”

$$P_S(t) = P_S(t-1) - P_{Sd}(t) + P_{Sc}(t); \quad t = 1, \dots, n \quad (13)$$

Storage battery limit on the initial state

$$P_S(t) + P_{s_0} \leq P_{Smax}; \quad t = 1 \quad (14)$$

Initial state of the battery 1

$$P_{Sd}(t) = P_{Sinitial}(0) \quad (15)$$

For the storage system 2 or battery 2:

Storage battery 2 limits in each time interval “ $t$ ”

$$0 \leq P_{S_2}(t) \leq P_{Smax_2}(t); \quad t = 1, \dots, n \quad (16)$$

Storage battery 2 maximal discharge limits in each time interval “ $t$ ”

$$P_{Sd_2}(t) \leq P_{Sdinitial_2}(1) \cdot X_2(t); \quad t = 1, \dots, n; \quad X = 0 \text{ or } 1 \quad (17)$$

Storage battery 2 maximal charge limits in each time interval “ $t$ ”

$$P_{Sc_2}(t) \leq P_{Scmax_2}(t) \cdot Y_2(t); \quad t = 1, \dots, n; \quad Y = 0 \text{ or } 1 \quad (18)$$

The battery 2 cannot charge and discharge at the same time in each time interval “ $t$ ”

$$X_2(t) + Y_2(t) \leq 1; \quad t = 1, \dots, n; \quad X_2, Y_2 = 0 \text{ or } 1 \quad (19)$$

Storage battery 2 maximal discharge limits in each time interval “ $t$ ” considering the battery 2 state storage in time interval  $t-1$

$$P_{Sd_2}(t) - P_{S_2}(t-1) \leq 0; \quad t > 1, \dots, n \quad (20)$$

Storage battery 2 maximal charge limits in each time interval “ $t$ ” considering the battery 2 state storage in time interval  $t-1$

$$P_{Sc_2}(t) + P_{S_2}(t-1) \leq P_{Smax_2}(t); \quad t > 1, \dots, n \quad (21)$$

Balance state of the battery 2 on the initial state

$$P_{S_2}(t) = P_{s_{20}} - P_{Sd_2}(t) + P_{Sc_2}(t); \quad t = 1 \quad (22)$$

Balance state of the battery 2 in each time interval “ $t$ ”

$$P_{S_2}(t) = P_{S_2}(t-1) - P_{Sd_2}(t) + P_{Sc_2}(t); \quad t = 1, \dots, n \quad (23)$$

Storage battery 2 limit on the initial state

$$P_{S_2}(t) + P_{s_{20}} \leq P_{S2max}; \quad t = 1 \quad (24)$$

Initial state of the battery

$$P_{Sd_2}(t) = P_{S2initial}(0) \quad (25)$$

Capacity limits of distribution lines

$$\left| V_i(t) \cdot \left[ (V_i(t) - V_j(t)) \cdot y_i \right]^* + V_i(t) \cdot \left( V_i(t) \cdot \left( \frac{1}{2} \cdot y_i \right)^* \right) \right| \leq P_{imax}(t); \quad i = 1, \dots, N_d - 1; \quad j \neq i; \quad j = 2, \dots, N_d; \quad t = 1, \dots, n \quad (26)$$

For the succeeding time slices the constraints are the same. The existent storage energy ( $P_s$ ) is updated between time slices. If considered a large number of time slices, it is possible to minimize the operation costs and optimize the storage management.

The Distribution Network constraints have been taken into account in the formulation. In this particular case, the active power loss is a squared function of the current flowing through the lines. This function can be linearized in the objective function if is necessary. However, if is necessary to carry out the study without linearization, other optimization technique could be used. In this case the Mixed–Integer Quadratic Programming

(MIQP) has been used. However, there are other optimization techniques, for example, the benders decomposition is a suitable technique for solving the non-linear model using the most adequate solver in platform of GAMS system. Benders decomposition [30] is a solution method for solving certain large-scale optimization problems. Instead of considering all decision variables and constraints of a large-scale problem simultaneously, Benders decomposition partitions the problem into multiple smaller problems. Since computational difficulty of optimization problems increases significantly with the number of binary variables and constraints, solving these smaller problems iteratively can be more efficient than solving a single large problem. Hence, this technique can be used on the future development and application of the proposed methodology on a large power system.

## **5- Mathematical Solution Methods**

The optimal dispatch problem formulated in the Section 4 is a MIQP model with two types of variables that are continuous and binaries. The nature of the formulated problem is combinatorial. As a consequence, in the specialized literature, several solution techniques have been proposed to solve the unit commitment problem such as heuristics [31]–[33], dynamic programming [34]–[36], mixed-integer linear programming [37], [38], Lagrangian relaxation [39], simulated annealing [40] and evolution-inspired approaches [41]–[43] can be adopted to solve the intelligent microgrid scheduling. In this paper, the MIQP has been chosen firstly to obtain a global optimal solution. On the other hand, to tackle complex real world problems, scientists have been looking into natural processes and creatures—both as model and metaphor—for years. Optimization is at the heart of many natural processes including Darwinian evolution, social group behavior and foraging strategies. Over the last few decades, there has been remarkable growth in the field of nature-inspired search and optimization algorithms. Currently these techniques are applied to a variety of problems, ranging from scientific research to industry and commerce. The two main families of algorithms that primarily constitute this field today are the evolutionary computing methods and the swarm intelligence algorithms. Although both families of algorithms are generally dedicated towards solving search and optimization problems, they are certainly not

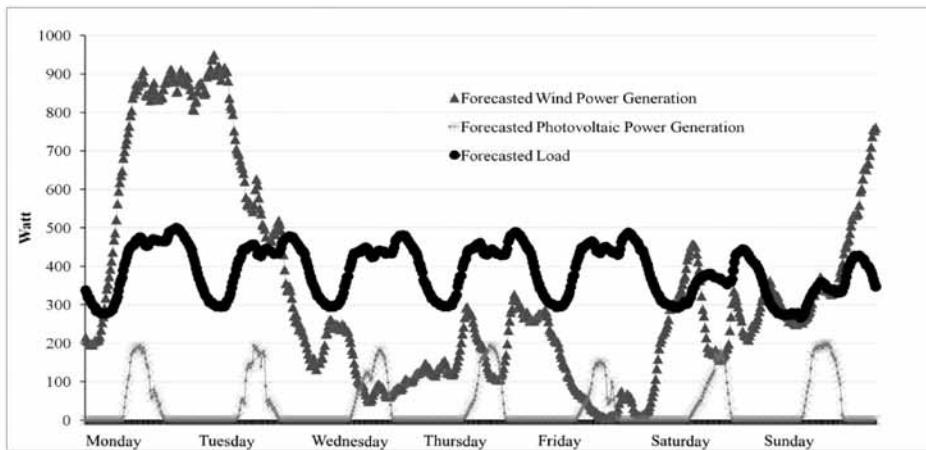
equivalent, and each has its own distinguishing features. Reinforcing each other's performance makes powerful hybrid algorithms capable of solving many intractable search and optimization problems. In [21], [22], [44], it has been proved that meta-heuristics techniques are also very attractive to solve this problem in a sense, which it has to escape from a local minimum. It allows the search process to find out acceptable solutions. However, deterministic optimization technique like MILP has been proven to be the adequate solution of the sated MILP optimization problem handling efficiently the decision to be taken expressed on the binary variables [20]. In all these references, the problem has been formulated as MILP; the microgrid has islanding operation and without taken into accounts the distribution active power losses. The formulation in this paper is a non-linear problem. To solve this problem the MIQP optimization technique has been used on this paper, which is still to be very efficient to solve this kind of problem fully handling the binary variables. The microgrid can operate isolated and connected to distribution network and the distribution network active power losses has been taken into account.

#### A) *Mixed Integer Linear Programming (MIQP)*

The MIQP optimization technique has been chosen for solving the optimal dispatch of renewable distributed energy park problem. The main reason for it is the convergence guarantee to the optimal solution in a finite number of steps [45] while providing a flexible and accurate modeling framework. In addition, during the search of the problem tree, information on the proximity to the optimal solution is available. Efficient mixed-integer quadratic programming such as the branch-and-cut algorithm based on GAMS platform under CPLEX name has been used in this paper.

## 6- Test Case

A real test case has been performed to illustrate the generality and the effectiveness of the proposed optimization methodology. This study case corresponds to microgrid Laboratory of Renewable and storage Equipments (see Fig.1). The forecasted wind power generation, photovoltaic power generation and load used to perform the optimization model are shown on Figure 4.



**Fig.4. Forecasted Wind Power, Photovoltaic and Load for one week–672 periods–15 minutes each**

The calculation may be executed for fifteen minutes, one hour, one day, one week, one month or for every fifteen minutes in a whole year (8760 h, 35040 time intervals). The expected results of the optimization problem are the optimal operating scheduling of how the equipments should be used by an optimal and intelligent way, and summary results for the considered scenario, such as the total cost, power generation in each time interval of fifteen minutes during one week scheduling.

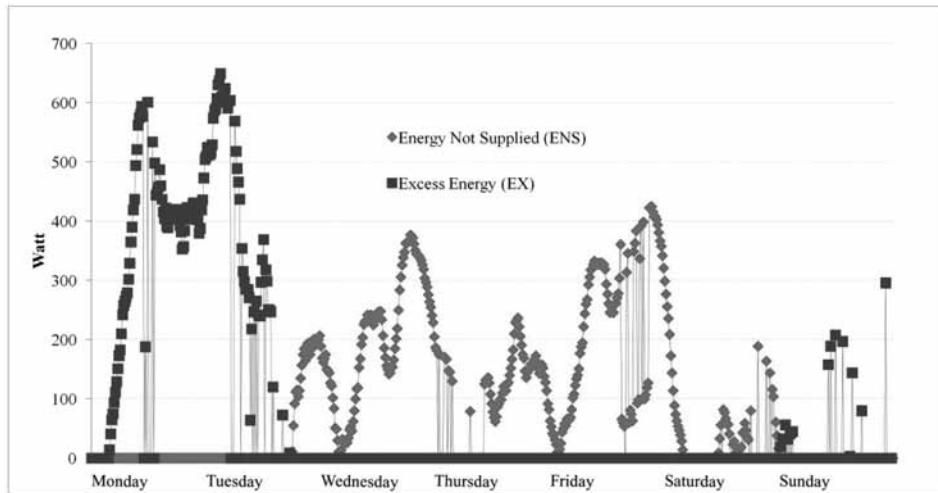
The optimization problem of Laboratory equipments has been analyzed for one week period, 672 time intervals for fifteen minutes sequential time each. In order to schedule the generation units, a cost of each generation technology is established. In the context of intelligent grid towards smart-grid, is expected that online dynamic prices provided by the electricity market to SCADA of the smart-grid via smart-metering. In this case, the considered prices are: Wind energy cost is 0.4 Euro/kWh; photovoltaic energy cost is 0.4 Euro/kWh; fuel cell energy cost is 0.9 Euro/kWh; storage energy discharging cost is 0.6 Euro/kWh; storage energy charging cost is 0.4 Euro/kWh; un-delivered energy cost is 1.5 Euro/kWh and the excess energy cost is 0 Euro/kWh. These values are estimated to carry out the optimal schedule of the equipments, but these values are not limited to those here exposed, an others values may be used instead. This fact should

not affect the proposed methodology, but of course the results, since these costs values are used on the optimization problem.

Some important results as well as the optimal renewable energy dispatch have been obtained taking into account the marginal cost of each generation technology and the forecasted wind power, photovoltaic power and loads.

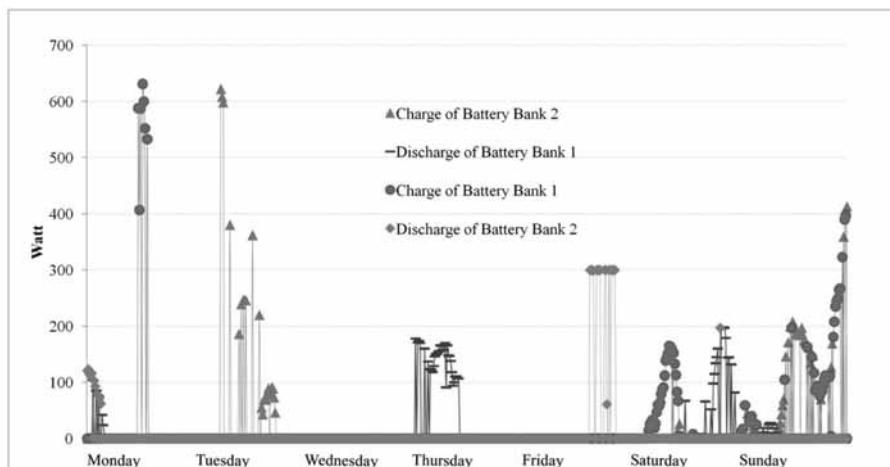
For the application of the methodology a digital program in GAMS platform has been developed. The optimization problem has been tested on A PC compatible with Processor Core Duo CPU, U9400@1.40-GHz, 3 GB of random-access-memory (RAM), the Windows 7 Professional, 32-bit Operating System and GAMS compiler have been used. The average CPU time is 0.14 s with 1787 iterations.

Figure 5 depicts all resulted values of the Energy excess and the un-served energy obtained from optimal dispatch problem for one week from 00:00 hours of Monday January 10, 2011 to 23:45 hours of Sunday 16 January, 2011 respectively. In this figure, is very clear that from 4:00 Hours of Monday to 16:15 Hours of Tuesday the wind speed was very high (see Fig.4), consequently the wind power generation is high accordingly, the load is less than the wind power generation and therefore, may be covered by only this power generation type. Thus, in this case there are an exceeding power generations of different type. This exceeding power is not only used for battery bank 1 and bank 2 charging (see Fig. 6) but also the additional power is injected to the main grid. This scenario may also occur on some time intervals on Saturday and Sunday respectively, but with minor impact values (see Figs. 4, 5 and 6). On the same figure 5, it can be noted the un-served energy occurs with different variation from the 00:30 Hours of Wednesday to 3:15 Hours inclusively. This un-served energy may be translated on loads shedding, which is intensified from Friday to Saturday inclusively. Other scenario of energy curtailment with certain intermittence takes place on Sunday, January 16 of 2011. These loads shedding may occur because the loads are most enough than the power generation. The storage systems (Battery Bank 1 and 2) try to alleviate the situation of energy no supplied, and therefore they have been discharged accordingly (see Fig. 6), but they cannot supply all loads due to its capacities limit.



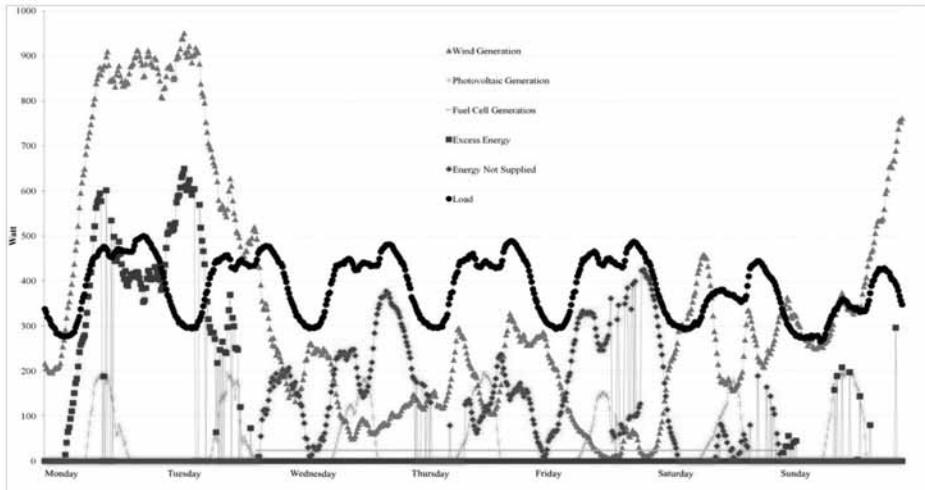
**Fig.5. Obtained results of energy excess and no-supplied for one week dispatch**

Figure 6 illustrates the batteries (bank 1 and 2) charging and discharging respectively. It can be noted that the time intervals of batteries (bank 1 and 2) charging corresponds to the time intervals when there is power generation in excess. It can also be observed that the time interval of battery (Bank 1 and 2) discharging correspond to the time interval of un-served energy.



**Fig.6. Obtained results of charge and discharge of the storage systems for one week dispatch**

Figure 7 shows the power generation by Fuel cell is dispatched from 17:45 Hours of Tuesday to 23:45 hours of Saturday when the loads are more than the sum the other generated power.



**Fig.7. Obtained results of optimal dispatch of microgrid for one week dispatch**

Figure 7 depicts all results of optimal dispatch of the DER connected into micro-grid. On this Figure, it can be observed that the photovoltaic power generation is an effective power from Monday to Sunday and more exactly every day from 8:00 Hours to 17:00 Hours approximately.

#### NOMENCLATURE

$C_w$	Energy cost coefficient (Euro/kWh) generated by Wind turbine
$C_{pv}$	Energy cost coefficient (Euro/kWh) generated by Photovoltaic panels
$C_{Fc}$	Energy cost coefficient (Euro/kWh) generated by Fuel Cell
$C_{Sc}, C_{Sc2}$	Energy cost coefficient (Euro/kWh) for Battery bank 1 and battery bank 2 charge respectively
$C_s, C_{sd2}$	Energy cost coefficient (Euro/kWh) for Battery bank 1 and battery bank 2 discharge respectively
$C_{ENS}$	Energy cost coefficient (Euro/kWh) for Energy no served to loads

$C_{EX}$	Energy cost coefficient (Euro/kWh) for Excess generated energy
$P_w$	Generated power by Wind turbine (kW)
$Nd$	Nodes number of distribution network
$P_v$	Generated power by Photovoltaic panels (kW)
$P_{Fc}$	Generated power by Fuel cell (kW)
$P_{Sc}, P_{Sc2}$	Storage power battery bank 1 and bank 2 charge (kW) respectively
$P_{Sd}, P_{Sd2}$	Storage battery bank 1 and bank 2 power discharge (kW) respectively
$P_{ENS}$	Un-delivered power (kW)
$P_{EX}$	Excess generated power (kW)
<b>Load</b>	Load power (kW)
	Active power losses of distribution network (kW)
$t$	Time slice (hour)
$X, X_2$	Binary variable corresponding to battery bank 1 and bank 2 charging respectively
$Y, Y_2$	Binary variable corresponding to battery bank 1 and bank 2 discharging respectively
$Ps$	Storage battery power state (kW)
$P_{W_{min}}, P_{W_{max}}$	Wind power generation capacity (kW) minimum and maximum limit respectively
$P_{V_{max}}$	Photovoltaic power generation capacity (kW) limit
$P_{FC_{max}}$	Fuel cell power generation capacity (kW) limit
$P_{S_{max}}, P_{S_{max2}}$	Storage battery bank 1 and bank 2 maximum capacity (kW) limit respectively
$P_{Sd_{initial}}, P_{Sd_{initial2}}$	Storage battery bank1 and bank 2 initial discharge (kW) limit respectively
$P_{S_{cm_{max}}}, P_{S_{cm_{max2}}}$	Storage battery bank1 and bank 2 charge (kW) limit respectively
$P_{so}, P_{so2}$	Storage battery bank 1 and bank 2 initial charge (kW) respectively

$V_i, V_j$	Voltage of bus i and bus j of the distribution network (V)
$y_i$	Admittance of the lines connected into node i of distribution network ( $\Omega$ )
<b>ER</b>	Engineering Recommendations
<b>E R G59/1</b>	Recommendations for the connection of embedded generating plant to the Regional Electricity Companies' distribution systems

## 7- Conclusions

In this paper an optimal operation of an intelligent microgrid managed by a VPP is presented and discussed. The main goal is to decide the best VPP management strategy to minimize the generation costs of wind energy, photovoltaic energy, fuel cell energy and optimize storage charging and discharging time subjected to all the operation technical constraints and controlled by the VPP developed software, mini-SCADA and PLC.

The dispatch has been formulated as a MIQP problem and solved by deterministic optimization techniques that have been developed and tested to a real case study presented and discussed in this paper. Performance of optimization technique has been studied demonstrating that the MIQP is the adequate technique to solve this kind of problem, handling effectively the binary decision variables of the problem choice.

The application of the methodology to a real case presented in the Laboratory for one week period, 672 time intervals, demonstrates the effectiveness, and the robustness of the proposed model. It has also been verified that it has a very low execution time for solving a MIQP problem. The proposed model can help the operation engineer to minimize the operation cost of the generations' units and storage systems by an intelligent and optimal way, taking into account the reliability expressed in the undelivered energy cost encouraging the application of this methodology to a large power system.

## **References**

- [1] K. Alanne, A. Saari, “Distributed energy generation and sustainable development”, *Renew Sust Energy Rev* 2006; 10(6): 539–58.
- [2] C. Marnay, G. Vankataramanan, “Microgrids in the evolving electricity generation and delivery infrastructure”, *IEEE Power eng. Soc. Gen. Meet.*; 2006, pp. 18–22.
- [3] O. Alsayegh, S. Alhajraf, H. Albusairi, “Grid-connected renewable energy source systems: Challenges and proposed management schemes”, *Energy Conversion and Management* 51 (2010) 1690–1693.
- [4] F. Katiraei, M.R. Iravani, “Power management strategies for a microgrid with multiple distributed generation units”, *IEEE Trans. on Power Syst.*, 2006;21(4):1821–31.
- [5] European Commission, “European SmartGrids technology platform: Vision and strategy for Europe’s electricity networks of the future” (April) (2006). [Online]. Available: [http://ec.europa.eu/research/energy/pdf/smartgrids\\_en.pdf](http://ec.europa.eu/research/energy/pdf/smartgrids_en.pdf) <http://www.smartgrids.eu>
- [6] A.D. Hawkes, M.A. Leach, “Modelling high level system design and unit commitment for a microgrid”, *Applied Energy* 86 (2009) 1253–1265.
- [7] E. Ghiani, S. Mocci, F. Pilo, “Optimal Reconfiguration of Distribution Networks According to the Microgrid Paradigm.”, *International Conference on Future Power Systems*, 2005, (November) (2005).
- [8] H. H. Zeineldin, E. F. El-Saadany, M. M. A. Salama, “Distributed Generation Micro-Grid Operation: Control and Protection”, *Power Systems Conference: Advanced Metering, Protection, Control, Communication, and Distributed Resources*, 2006, (March) (2006).
- [9] H. Ren, W. Gao, “A MILP model for integrated plan and evaluation of distribution energy systems”, *Applied Energy*, 87 (2010) 1001–1014.
- [10] P. Piagi, R. H. Lasseter, “Autonomous control of Microgrids”, *IEEE Power Engineering Society General Meeting*, 2006, (June) (2006).

- [11] A. Carlos, T. Hernandez–Aramburo, C. Green, N. Mugniot, “Fuel Consumption Minimization of a Microgrid”, IEEE Trans. on Indus. App., vol. 41, n. 3, (2005) 673 – 682.
- [12] W. El–Khattam, K. Bhattacharya, Y. Hegazy, Member, M. M. A. Salama, “Optimal Investment Planning for Distributed Generation in a Competitive Electricity Market”, IEEE Trans. on Power Syst., vol. 19, No.3, (August) (2004).
- [13] T. Niknam, A. Khodaei, F. Fallahi, “A new decomposition approach for the thermal unit commitment problem”, Applied Energy 86 (2009) 1667–1674.
- [14] F. Shahnia, R. Majumder, A. Ghosh, G. Ledwich, F. Zare, “Operation and control of a hybrid microgrid containing unbalanced and nonlinear loads”, Electric Power Systems Research 80 (2010), 954–965.
- [15] J.I.S. Martin, I. Zamora, J.J.S. Martin, V. Aperribay, P. Eguia, “Hybrid fuel cells technologies for electrical microgrids”, Electric Power Systems Research 80 (2010), 993–1005.
- [16] E. Mashhour, S.M. Moghaddas–Tafreshi, “Integration of distributed energy resources into low voltage grid: A market–based multiperiod optimization model”, Electric Power Systems Research 80 (2010), 473–480.
- [17] Z. Zhang, X. Huang, J. Jiang, B. Wu, “A load–sharing control scheme for a microgrid with a fixed frequency inverter, Electric Power Systems Research 80 (2010), 311–317.
- [18] S.P. Chowdhury, S. Chowdhury, P.A. Crossley, “Islanding protection of active distribution networks with renewable distributed generators: A comprehensive survey”, Electric Power Systems Research 79 (2009), 984–992.
- [19] P. Mancarella, G. Chicco, “Global and local emission impact assessment of distributed cogeneration systems with partial–load models”, Applied Energy 86 (2009) 2096–2106.
- [20] Hugo Morais, Péter Kádár, Pedro Faria, Zita A. Vale, H.M. Khodr, “Optimal scheduling of a renewable micro-grid in an isolated load area using mixed-integer linear programming”, Renewable Energy, Vol. 35, Issue 1, January 2010, pp. 151-156.

- [21] Z.A. Vale, P. Faria, H. Morais, H.M. Khodr, M. Silva, P. Kádár, “Scheduling distributed energy resources in an isolated grid — An artificial neural network approach,” PES General Meeting, 2010 IEEE , vol., no., pp.1-7, 25-29 July 2010.
- [22] H.M. Khodr, Z.A. Vale, C. Ramos, J.P. Soares, H. Morais, P. Kádár, “Optimal methodology for renewable energy dispatching in islanded operation,” Transmission and Distribution Conference and Exposition, 2010 IEEE PES , vol., no., pp.1-7, 19-22 April 2010.
- [23] GAMS Development Corporation, GAMS—The Solver Manuals, GAMS User Notes. Washington, DC, (January) (2001).
- [24] <http://www.gams.com>
- [25] <http://www.progea.com/software-automation-scada/movicon-11/movicon-11-xml-based.htm>
- [26] <http://www.mathworks.com/products/matlab/>
- [27] H. Morais, M. Cardoso, L. Castanheira, Z. Vale, I. Praça, “A Decision-Support Simulation Tool for Virtual Power Producers”, International Conference on Future Power Systems, (2005).
- [28] H. Ferenc, “Magyarország els folyamatosan hálózatra termel mini nap er mve”, in Elektrotechnika, Hungarian, 7–8, (2004) 232–233.
- [29] S. Roland, “A napelem cellák vizsgálatának kutatási eredményei”, in Elektrotechnika, Hungarian, 2, 8–9 (2006).
- [30] H.M. Khodr, J. Martínez-Crespo, “Integral methodology for distribution systems reconfiguration based on OPF using benders decomposition technique,” IET Generation, Transmission & Distribution, June 2009 – Vol. 3, Issue 6, pp. 521-534.
- [31] F. N. Lee, “Short-term thermal unit commitment—A new method,” IEEE Trans. on Power Syst., vol. 3, no. 2, (May) (1988) 421–428.
- [32] C. Li, R. B. Johnson, and A. J. Svoboda, “A new unit commitment method,” IEEE Trans. on Power Syst., vol. 12, no. 1, (February) (1997) 113–119.
- [33] T. Senju, K. Shimabukuro, K. Uezato, and T. Funabashi, “A fast technique for unit commitment problem by extended priority list,” IEEE Trans. on Power Syst., vol. 18, no. 2, (May) (2003), 882–888.

- [34] W. L. Snyder, H. D. Powell, and J. C. Rayburn, “Dynamic-programming approach to unit commitment,” IEEE Trans. on Power Syst., vol. 2, no. 2, (May) (1987) 339–350.
- [35] W. J. Hobbs, G. Hermon, S. Warner, and G. B. Sheblé, “An enhanced dynamic programming approach for unit commitment,” IEEE Trans. on Power Syst., vol. 3, no. 3, (August) (1988) 1201–1205.
- [36] Z. Ouyang and S.M. Shahidehpour, “An intelligent dynamic-programming for unit commitment application,” IEEE Trans. on Power Syst., vol. 6, no. 3, (August) (1991) 1203–1209.
- [37] T. S. Dillon, K. W. Edwin, H. D. Kochs, and R. J. Tand, “Integer programming approach to the problem of optimal unit commitment with probabilistic reserve determination,” IEEE Trans. on Power Apparatus and Syst., vol. PAS-97, no. 6, (November–December) (1978) 2154–2166.
- [38] J. Medina, V. H. Quintana, and A. J. Conejo, “A clipping-off interior point technique for medium-term hydro–thermal coordination,” IEEE Trans. on Power Syst., vol. 14, no. 1, (February) (1999) 266–273.
- [39] W. Ongsakul and N. Petcharaks, “Unit commitment by enhanced adaptive Lagrangian relaxation,” IEEE Trans. on Power Syst., vol. 19, no.1, (February) (2004) 620–628.
- [40] G. K. Purushothama and L. Jenkins, “Simulated annealing with local search—A hybrid algorithm for unit commitment,” IEEE Trans. on Power Syst., vol. 18, no. 1, (February) (2003) 273–278.
- [41] J. M. Arroyo and A. J. Conejo, “A parallel repair genetic algorithm to solve the unit commitment problem,” IEEE Trans. on Power Syst., vol. 17, no. 4, (November 2002) 1216–1224.
- [42] C. C. A. Rajan and M. R. Mohan, “An evolutionary programming-based tabu search method for solving the unit commitment problem,” IEEE Trans. on Power Syst., vol. 19, no. 1, (February) (2004) 577–585.
- [43] I. G. Damousis, A. G. Bakirtzis, and P. S. Dokopoulos, “A solution to the unit commitment problem using integer-coded genetic algorithm,” IEEE Trans. on Power Syst. vol. 19, no. 2, (May) (2004) 1165–1172.

- [44] Z.A. Vale, H. Morais, H.M. Khodr, B. Canizes, J.P. Soares, “Technical and economic resources management in smart grids using heuristic optimization methods,” Power and Energy Society General Meeting, 2010 IEEE, vol., no., pp.1-7, 25-29 July 2010.
- [45] G. L. Nemhauser and L. A. Wolsey, Integer and Combinatorial Optimization. New York: Wiley–Interscience, (1999).