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Demand Priority in a Power System With Wind Power Contribution Load Shedding Scheme Based

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ABSTRACT

The load shedding scheme has been extensively implemented as a fast solution for unbalance conditions. Therefore, it's crucial to investigate supply-demand balancing in order to protect the network from collapsing and to sustain stability as possible, however, its implementation is mostly undesirable. One of the solutions to minimize the amount of load shedding is the integration renewable energy resources, such as wind power, in the electric power generation could contribute significantly to minimize power cuts as it is able to positively improve the stability of the electric grid. In this paper propose a method for shedding the load base on the priority demands with incorporating the wind power generated. The higher priority demands are fed with a reliable wind energy resource in order to protect them from shedding under contingency condition such as high overloading by the real-time monitoring of the network. The main objective of this research is to sustain enough power for higher important loads where possible and accurate amount of load shedding while keeping the load under the available power threshold. In such a case, the important loads such as health cares are kept intact without any interruption as possible. The simulation results prove the effectiveness and practicality of the applied method paving the way for possible applications in power systems.

Keywords: Load shedding, Load matrix, Importance matrix, Wind power penetration.

عزل الاحمال بالاعتمادعلى اولوية الحمل في نظام القدرة بمساهمة قدرة الرياح

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الخلاصة

يطبق نظام عزل الأحمال على نطاق واسع كحل سريع لظروف عدم الاتزان للشبكة الكهربائية . لذلك ، لأهمية تحقيق الموازنة مابين التوليد والحمل المطلوب وذلك من أجل حماية الشبكة الكهربائية من الانهيار وايظا الحفاظ على استقراريتها قدر المستطاع ، ومع ذلك فإن تنفيذ نظام العزل هو أمر غير مرغوب فيه. إن أحد الحلول لتقليل مقدار عزل الاحمال عن طريق مصادر الطاقة المتجددة ، مثل طاقة الرياح ، للمساهمة في زيادة توليد الطاقة الكهربائية حيث يمكن أن تسهم بشكل كبير في

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تقليل انقطاع التيار الكهربائي وايظا قدرتها على تحسين استقرار الشبكة الكهربائية بشكل إيجابي. في هذ البحث ،تم اقتراح طريقة لعزل الاحمال بالاعتماد على الأولوية للاحمال من حيث اهميتها بمساهمة طاقة الرياح. يتم تزويد الاحمال الأعلى اهمية بالطاقة وبشكل مستمر وموثوق به من أجل حمايتهم من العزل تحت ظروف الطوارئ مثل الزيادة المفاجاة والعالية للاحمال وذلك من خلال المراقبة المستمرة للشبكة وفي نفس الوقت تخفيض الطاقة غلى الاحمال الأقل اهمية. الهدف الرئيسي من هذا البحث هو الحفاظ على الطاقة لأحمال ألاعلى اهمية حيثما أمكن ذلك وكمية دقيقة للاحمال المقللة مع الحفاظ على الاحمال تحت عتبة الطاقة المتوفرة. في مثل هذه الحالة ، يتم الاحتفاظ بالأحمال المهمة مثل المراكز الصحية دون أي انقطاع ممكن. النتائج التي تم الحصول عليها تبين مدى فاعلية الطريقة العملية وان تطبيقها يمهد الطريق للتحسينات الممكنة في نظام القدرة الكهربائية.

الكلمات الرئيسية: اطفاء الاحمال, مصفوفة الحمل, مصفوفة الاهمية, طاقة الرياح.

1. INTRODUCTION

Most non-developing and under developing countries strive hard to tackle the situation of power crisis and to combat the imbalance between supply-demand power, especially in the case of increasing of the population which lead to the load exceeds the limitation of the network. Thus, it will be a challenge to the power system to cater the increasing of demand while maintaining the system stability**,Tuaimah, 2010; Grigsby, 2007.** On other hand, the severe disturbance is given the highest importance which required to shed some loads from the network in order to maintain the stability and security of the system when these type of contingencies are occurred**,Abdulsada and Tuaimah, 2017**. In this scheme, load shedding (LS) is a necessary strategy to reduce the requirements of some loads to compensate for big difference and to keep the load under specified power**, Al-rawi, 2018; Shekari, et al.**, **2016**.

Several of the conventional techniques shedding the loads–under frequency load shedding (UFLS) and under voltage load shedding (UVLS) are independent design, either excessive or insufficient and without estimating the actual power imbalance. These techniques may have a slow response time so that this fact may lead to problems in power system quality and tripping in the total power system because of the restriction on the real-time monitoring **,Taylor**, **1992**.

Adaptive LS scheme then was developed to improve the traditional LS methods by adaptive selection the parameters of the proposed scheme and estimation the rate change of the network frequency through measuring the magnitude of the disturbance **, Terzija, 2006; Seyedi and Pasand, 2009. Saffarian and Pasand, 2011; Ghaleh, et al., 2011,** were proposed combinatorial algorithms to combine (UF-UV) LS that the frequency and voltage signals are locally measured to enhance the adaptive LS method in the power system. **Manson, et al., 2014; Reddy and Srivastava, 2014**. were proposed an adaptive UFLS scheme taking into account the magnitude of the disturbance in order to find the location and the amount of load to be shed.

However, the operation of the conventional, adaptive and proposed LS scheme are unsuitable to perform in the large scale power system and unhandled the various forms of the contingencies. In addition, these technics are also incapable to shed a precise amount of the loads **,Lu, et al., 2016.** Therefore, there are a few research that works have done the shedding candidates are selected and the load categorization/priority based on load types of the systems. For example, the LS based on importance has been proposed for loads to progress the execution of the power system during contingencies and to minimize the impact of the LS on the consumers by taking the social factors into consideration **,Rao, et al., 2013; Laghari, et al., 2015; Esttaifan and Al-haddad, 2017.**

Therefore, these LS schemes do not consider the effects of the high penetration and the contribution of each wind generator on the LS performance of the system in their research. One of the solutions to minimize the amount of load shedding is the integration renewable energy resources, such as wind power (WP), into the electric power generation could contribute significantly to minimizing power cuts as it is the ability to positively improving the stability of the

electric grid. The permeation of WP is rising rapidly around the world in recent years in the power system and the major power plants are incorporated with the multiple WP generating units with considerable active power output**,Gao, et al., 2018**.
WP generation systems as the main part of sustainable energy sources are confirming the operation the network of the power system, therefore, their unavoidable influence on the operation the network of power systems along with their increasing penetration level to the power grid **,Ketabi and Fini, 2014; Das, et al., 2017.** A novel adaptive LS scheme is approached that considering the penetration of the WP generation into account. In the proposed scheme, improve the power precision so as to reduce the error of LS. effects of the WP output on the LS, thus cutting down the LS costs and even preventing the frequency overshoot**, Zhang, et al., 2015.** New online UFLS strategy considering the wind turbines is proposed in order to prevent the power system from frequency collapse.
At present, increasing wind turbines have been jointed to the network of the power system, so that it is allowed to attain the target of the less LS and quicker frequency recapture based on this strategy **, Li and Tang, 2017.** Recently, some works have been done regarding LS considering the impacts of WP while the large-scale wind farms become a salient feature in the modern power grid. Improved LS scheme considering wind generation by using the directional relays, power flow through feeders, and WP measurements to choose the feeders to be discrete during the LS such that is reduced the amount of loads required to be shed**, Huang, et al., 2017.**
In this work, we propose a LS strategy based on priority demands (PDs) considering the WP generation. Through this approach, we first prioritize the loads according to their importance into account the penetration of the WP. We test a practical case in the Iraqi national grid and the simulation results showed a reduction in demands while the supplied power to the important loads kept intact. The selective LS improved the system reliability and effectiveness for the critical loads.
This paper is organized in what follows, we first in section 2.1 underlay the categorization strategy of loads importance. Section 2.2 presents the main theoretical result of this work. We present the load shedding scheme based on PDs and drive the mathematical modeling of the shedding process. The impact of WP generation in the shedding requirements and suitable locations for the installation of wind turbines in Iraq is described in section 3. The response of a power system without the suggested penetration of the WP is shown in section 4.1. Finally, we put in section 4.2 the full system with the penetration of the WP in to test using real data.

2. METHODOLOGY OF LOAD SHEDDING

2.1 Loads Categorizations

Whenever there is a shortage of supply in a system, an alert is sent to the control center in order to release certain load demands. In the conventional technique, a whole feeder is switched off regardless of the load type which belongs to that particular feeder based upon the demonstrative calculations for keeping the system in nominal operating.
In practice, different types of loads, such as domestic, health care, etc. could be connected to a single feeder. Thus, that single feeder could have a variance of demand priorities which may be considered to include diverse types of loads. Hence, in the presented scheme, a feeder will have a priority mechanism based on the PDs.
In other words, any feeder included in a power system can be considered to have lower or higher importance predicated on the number and type of the loads e.g. critical or non-critical loads which connected to a particular feeder. So, non-critical loads which have been selected for shedding in order to preserve the power supply to the load with higher PDs.

Critically definition in this paper depends only on the nature of loads that are associated with its effect on the life safety of people, these loads consist of healthy installations such as hospitals, call center, and fire stations. Since such loads have high priority, it consists of criticality factor. Each type of load will have its own importance and can be categorized based on their criticality and the range of load importance distribution is shown in **Table.1.**

Table 1. Loads categorizations based on importance.

Categorization	Importance
Healthcare	0.9 – 1.0
Communication, Transportation	0.8 – 0.9
Security	0.7 – 0.8
Services, financial	0.6 – 0.7
Industrial	0.5 – 0.6
Commercial	0.4 – 0.5
Residential	0.3 – 0.4
Domestic	0.1 – 0.3

It's obvious from **Table. 1**, each category of loads will have its own importance value between (0.1 - 1.0) so the value of the importance will be increasing according to the criticality of the load itself. At the first type, which has been considered as critical loads like health care includes hospitals will have high importance value between (0.9 - 1.0). The second type is the communication installations that considered also as critical loads, but with the importance (0.8 - 0.9) such as data centers. Consequently, the last type of categorization which has been considered as non-critical loads (0.1 - 0.3) is the first one to be shed in the implemented scheme while the loads at the first type are the last one being shed.

2.2 Importance Scheme for Loads

In this section, we propose a reduction method to control network load distributions and to direct its resources to the most important services. To convert the actual geographical distributions of the loads in the network, we construct the load matrix (LM) as follows:

$$Load\ Matrix\ (LM) = \begin{bmatrix} a_{11} & \cdots\cdots & a_{1m} \\ a_{21} & & a_{2m} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots\cdots & a_{nm} \end{bmatrix}_{n\times m} \quad (1)$$

Where m = 1,2,3… index the network substations and n = 1,2,3… index the network feeders that connected to each substation, respectively.

For instance, a_{11} assign the first feeder of the first substation and so on. Matrix data formulation of the network feeders with various load categories based on PDs is convenient for optimization and mathematical handling, and also, for the syntheses of the control system nodes. Next, we construct a matrix analogous to the LM and refer to it as the importance matrix (IM):

$$Importance\ Matrix\ (IM)\ = \begin{bmatrix} \propto_{11} & \dots\dots & \propto_{1m} \\ \propto_{21} & & \propto_{2m} \\ \vdots & \ddots & \vdots \\ \propto_{n1} & \dots\dots & \propto_{nm} \end{bmatrix}_{n\times m} \quad (2)$$

Where m, n =1, 2, 3…, $\propto_{nm}$ is the importance factor assigned to each a_{nm} in LM, and its value normalized between (0.1-1.0) basing on the suggested categorization of loads in **Table.1**. When the criticality is high the $\propto_{nm}$ approach unity.
Obviously, matrices sizes are equal and depend on the number of a particular substation and feeders that interconnected in the network system.
A detailed flowchart that clarifies the implementation process of the proposed reduction of loads is as shown in the **Fig.1**:

1- Set the available power value and the demand of the load.
2- Construct load matrix LM in **Eq. (1).**
3- Define the importance matrix IM in **Eq.(2).**
4- When the first condition is takes place, all the loads will be operating and if not, then shedding load with the lowest $\propto_{nm}$
5- All the loads with high importance will be operating when the second condition is investigated, if not, then shedding the next load N + 1 with low priority in order to protect critical load as possible.

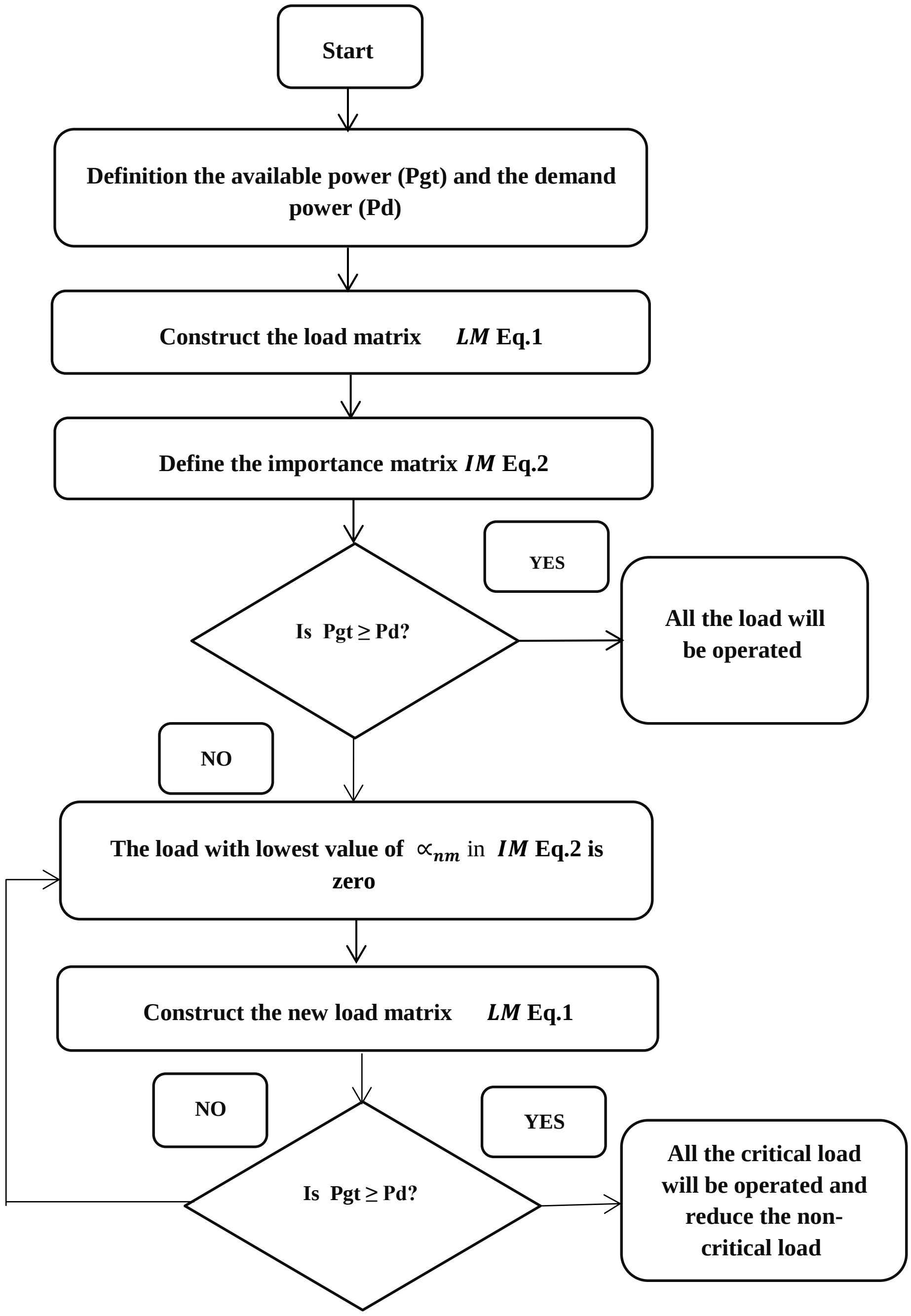

Figure 1. Flow chart of the shedding load process based on demand priority.

3. MAJOR IMPACTS OF WIND POWER ON THE LS SCHEME

For the LS scheme, the considering of WP generation in the shedding requirements will have some great influences on its validation. The importance of taking into account the integration of WP generation within the power system is to alleviating of demand-supply balancing and mitigating the influence of LS on the critical and non-critical loads. When the penetration of the WP generation is increasing, then the amount of loads required to be switched off should be reduced. In the opposite situation, the quantity of loads to be curtailed must be increased for avoiding the instability and breaking down of the power system. Therefore, the operation of the critical loads with interruption is minimized due to the contribution of wind generator and non-critical loads are considered for shedding. However, the most suitable locations for the installation of wind turbines in Iraq are calculated by Spanish company National Renewable Energy Centre (CENER) contracted with the Ministry of Science and Technology. As we can see that in **Fig. 2**, wind speed is shown random abrupt changes from region to another in the geographical area, therefore the best ever region in the south of Iraq at Shaikh Saad and Al-Dujaili reign.

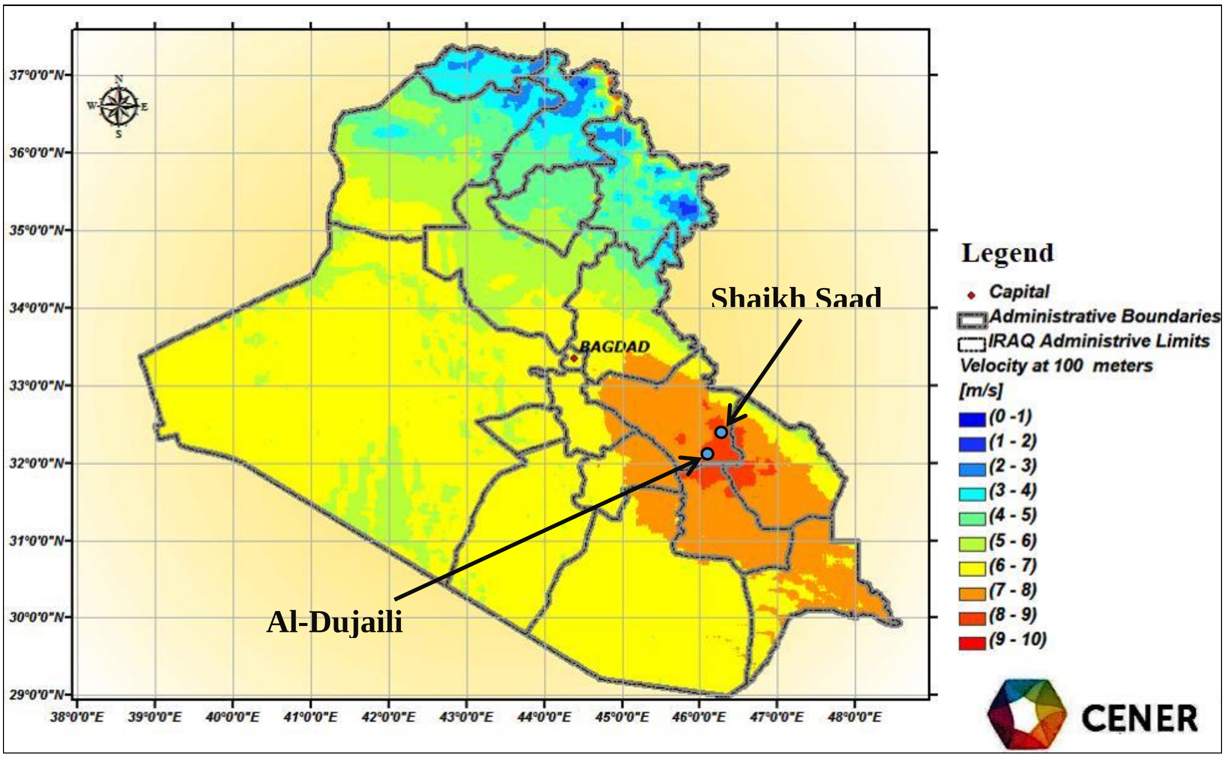

Figure 2. Iraqi wind atlas wind speeds at 100m height.

Of all the states, the common changes in wind speed are as depicted in **Fig.3**, the process of wind speed increases in a sudden and it's respectively stands for the process of wind speed gradually rising.

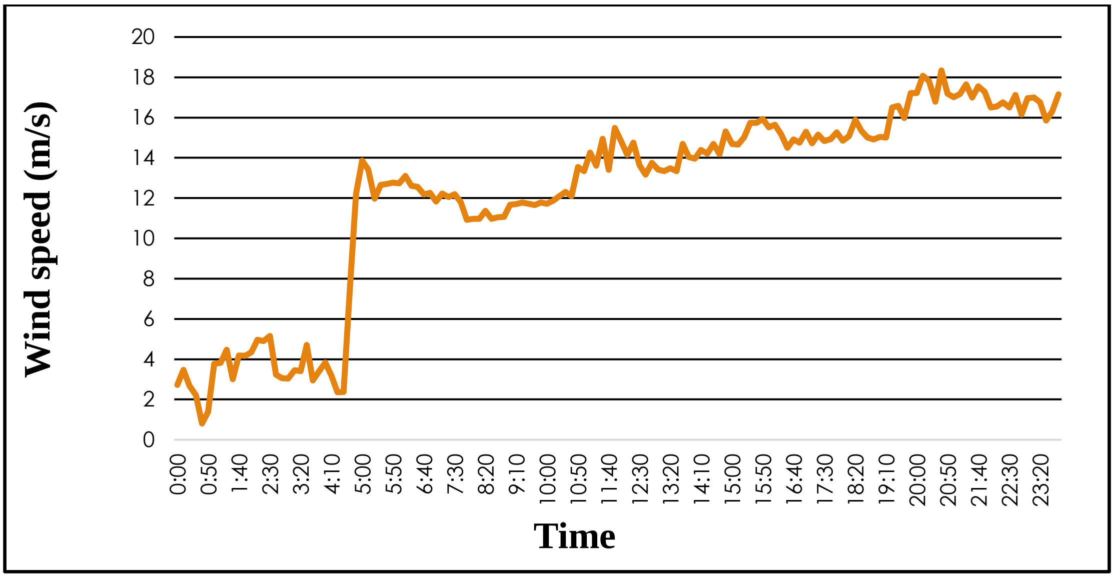

Figure 3. Wind speed changes in Wasit city in July month within 24 hours.

South of Iraq in the Wasit city is a good region to aggressive the goal of producing energy from renewable sources. **Fig. 4** shows the total energy production from wind sources for a certain location.

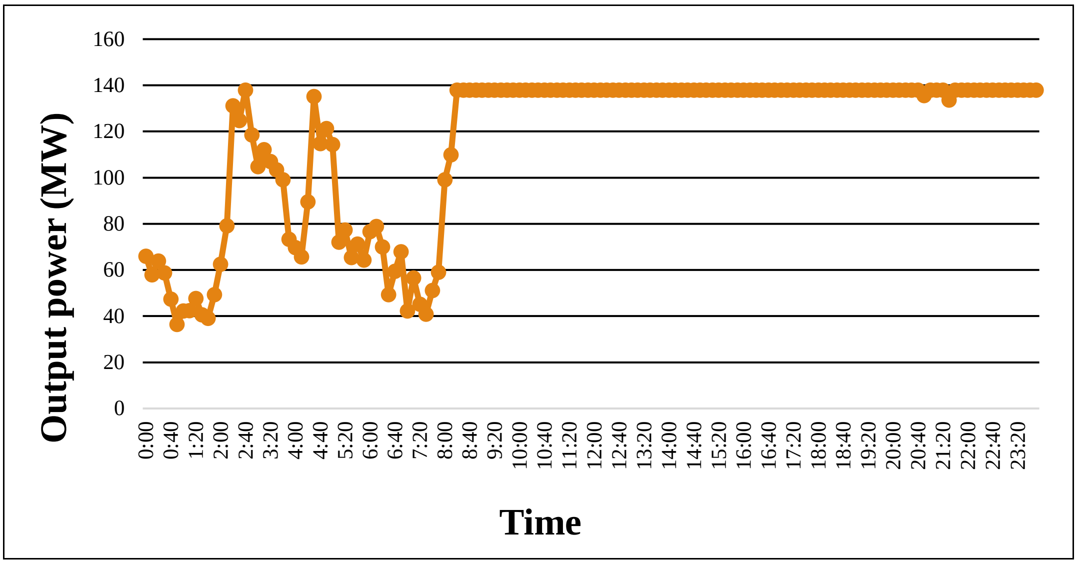

Figure 4. Wind output power in July month within 24 hours.

A wind turbine is selected from manufacturer catalogues to satisfy the calculated annual energy for a certain location. It was found that a 3.45MW capacity wind turbine model number V136 from VESTAS Company is the best wind turbine that satisfies the requirements of the present work and for wind speed available in Iraq. **Table.2** shows the data sheet of the selected wind turbine V136.

Table 2. Data sheet of wind turbine V136.

Rated Power (MW)	3.45
Turbine Class	IEC IIIA/IEC IIB
Cut-In Wind Speed (m/s)	3.0
Rated Wind speed (m/s)	10
Cut-Out Wind Speed (m/s)	22.5
Rotor Diameter (m)	631
Hub Height (m)	82-132
Swept Area (m²)	14,527
Control	Pitch and variable speed
Generator Type	Permanent magnet synchronous generator (PMSG)
Frequency (Hz)	50/60
WECS Type	4
Standard temperature range	-20°C to +45°C with a rating above 30°C

The power-speed curve of the selected wind turbine (V631) is shown in **Fig. 5**. The wind turbine output power is calculated as follows:

$$P_T = P_W \times C_P = \frac{1}{2} \rho A_T V_W^3 C_P \quad (3)$$

Where P_T is the mechanical output power in watt, ρ is air density (kg/m^3), C_p called the power coefficien, A_T is the rotor swept and recovered area of the wind turbine blades in (m2), r_T is the blade radius (m), and V_w, R is the rated wind speed (m/s). C_p represents the power coefficient of the rotor blades**(Yaramasu and Wu**, **2017)**.

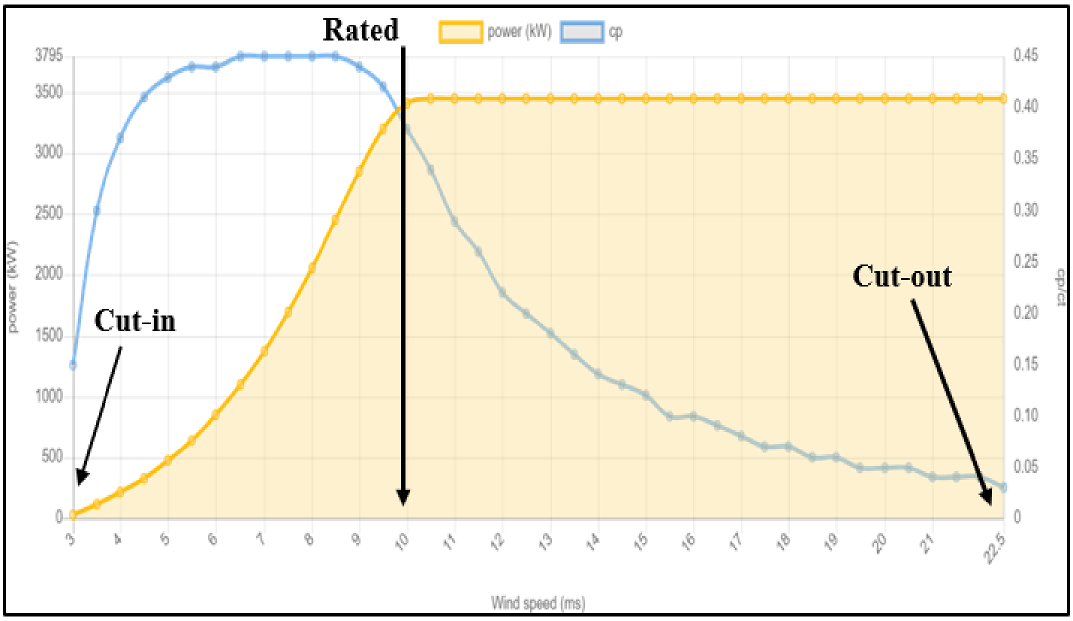

Figure 5. Power-speed curve for VESTAS V136 wind turbine.

Practical wind turbines have C_p in the range of 0.32 to 0.52. The transmitted power is generally deduced from the wind power, using the power coefficient C_p is defined below in terms of turbine coefficients C_1 to C_7:

$$C_p = C_1 \left(\frac{C_2}{\lambda_I} - C_3\beta - C_4\beta^2 - C_5\right) e^{-\frac{C_6}{\lambda_I}} + C_7\, \lambda_T \tag{4}$$

where β is the pitch angle, which can be adjusted by the pitch control system. λ_T corresponds to the optimal tip-speed ratio (TSR). λ_T is defined by the following:

$$\lambda_T = \lambda_T^{op} \frac{W_T\, r_T}{V_w\, R} \tag{5}$$

Variable-speed wind turbines operate at an optimal TSR value during all wind speed conditions. In Equation (4), λ_I is intermittent TSR and is related to λ_T and β as demonstrated below:

$$\frac{1}{\lambda_I} = \frac{1}{\lambda_T + 0.08\beta} - \frac{0.035}{\beta^3 - 1} \tag{6}$$

4. CASE STUDY AND SIMULATION SETUP

A real hourly demand data of the present year from the capital of Iraq (Baghdad city), were used to test and evaluate the simulation results of the load shedding and reducing program. The penetration of the renewable generation in the south of Iraq (Wasit city) has been significantly considering. The applied practical system includes a number of substations and each of them contains a number of feeders for Wasit National Grid (WNG). Choosing of a regional power network is according to the geography and the actual operating parameters of the substations are belonging to different categories of loads. The implemented scheme of the load shedding on WNG with and without penetration of WP is developed by using MATLAB of R2014 a version.

4.1. Load shedding based on importance without connecting wind energy resource to the network

A sample of the practical system which is considered as a case study for the WNG is defined within the LM structure in MW is shown below:

$$LM = \begin{bmatrix}
5.5 & 2.6 & 3.1 & 4.7 & 3.3 & 5.0 & 4.4 & 2.2 & 5.1 & 2.8 & 5.4 & 2.0 \\
3.2 & 4.2 & 4.4 & 5.5 & 2.7 & 4.7 & 3.7 & 5.0 & 3.0 & 4.0 & 3.3 & 4.4 \\
3.0 & 4.0 & 5.2 & 2.5 & 4.7 & 3.1 & 2.2 & 4.4 & 4.1 & 5.5 & 2.1 & 3.1 \\
4.9 & 2.5 & 4.5 & 3.3 & 5.5 & 2.9 & 5.3 & 2.0 & 2.7 & 3.2 & 5.0 & 4.0 \\
4.4 & 5.3 & 2.5 & 3.9 & 4.4 & 2.6 & 3.1 & 5.5 & 3.1 & 4.8 & 2.4 & 2.0 \\
3.1 & 2.3 & 3.9 & 4.5 & 5.2 & 4.7 & 5.0 & 2.3 & 4.4 & 3.5 & 5.1 & 2.0 \\
4.2 & 4.5 & 3.1 & 5.1 & 2.5 & 3.6 & 2.5 & 5.4 & 2.4 & 5.1 & 3.2 & 4.6 \\
2.8 & 5.1 & 4.6 & 3.2 & 4.1 & 2.1 & 5.4 & 3.1 & 4.1 & 3.3 & 2.1 & 4.2 \\
5.3 & 4.8 & 3.2 & 2.1 & 3.6 & 5.4 & 4.4 & 3.9 & 2.0 & 4.4 & 2.2 & 3.5 \\
3.9 & 5.2 & 2.5 & 4.3 & 4.3 & 3.0 & 5.5 & 4.8 & 3.9 & 2.0 & 3.2 & 5.1 \\
4.5 & 3.6 & 5.3 & 2.8 & 2.5 & 4.3 & 3.8 & 5.3 & 3.6 & 5.1 & 4.5 & 3.9 \\
2.3 & 3.3 & 4.6 & 5.2 & 3.9 & 4.7 & 5.1 & 2.6 & 5.0 & 2.7 & 4.6 & 2.1 \\
4.0 & 2.0 & 5.4 & 3.9 & 2.5 & 5.2 & 4.2 & 4.7 & 5.0 & 3.6 & 2.3 & 4.8 \\
5.2 & 5.3 & 2.6 & 4.7 & 5.0 & 3.6 & 4.1 & 2.2 & 4.4 & 5.5 & 3.6 & 4.0
\end{bmatrix}$$

Where m = 12, n = 14 represents the substations number (33/11) KV and the feeders number. These feeders will have different types of loads such as (lighting loads, commercial, industrial … etc.) under various priorities as shown in **Fig.6.**

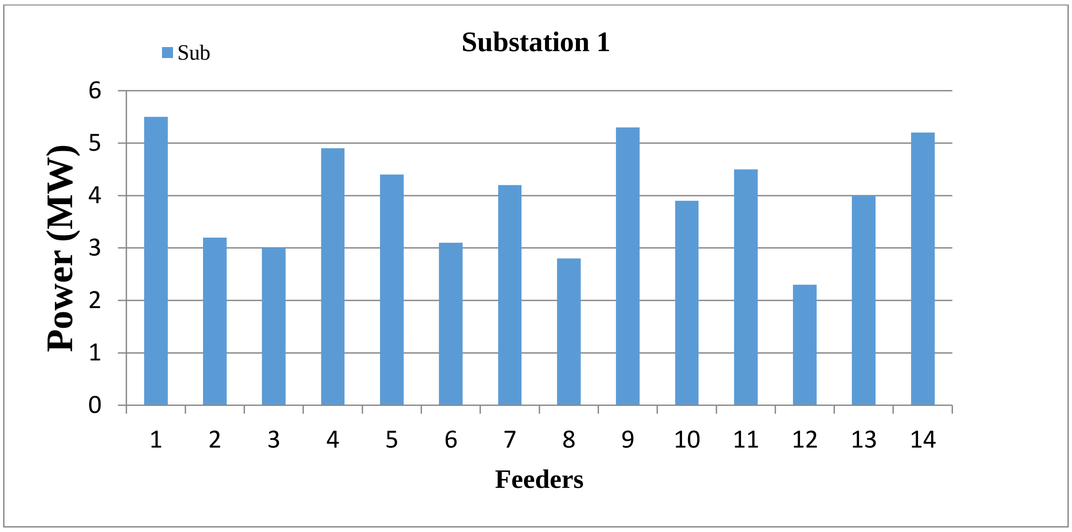

Figure 6. Practical Loads for 14 Feeders Connected to the First Substation

Each number in the matrix denotes the consumed power by load in (MW) which obtained from the particular control center unit. The total demand power for utilized a sample of the WNG is 649.8 MW. Each feeder in the LM will have its own priority based on the load category and this priority will be defined in the IM. Add this matrix also imported the real-life data as shown:

$$IM = \begin{bmatrix} 0.62 & 0.45 & 0.55 & 0.32 & 0.37 & 0.94 & 0.35 & 0.47 & 0.32 & 0.93 & 0.24 & 0.81 \\ 0.92 & 0.33 & 0.21 & 0.34 & 0.36 & 0.42 & 0.46 & 0.32 & 0.54 & 0.72 & 0.87 & 0.33 \\ 0.64 & 0.90 & 0.89 & 0.94 & 0.27 & 0.53 & 0.42 & 0.74 & 0.37 & 0.95 & 0.84 & 0.31 \\ 0.31 & 0.53 & 0.33 & 0.45 & 0.95 & 0.67 & 0.28 & 0.35 & 0.46 & 0.64 & 0.34 & 0.59 \\ 0.32 & 0.37 & 0.92 & 0.21 & 0.86 & 0.31 & 0.73 & 0.38 & 0.62 & 0.43 & 0.42 & 0.67 \\ 0.62 & 0.22 & 0.51 & 0.53 & 0.63 & 0.26 & 0.91 & 0.35 & 0.56 & 0.85 & 0.57 & 0.77 \\ 0.91 & 0.88 & 0.35 & 0.31 & 0.42 & 0.82 & 0.72 & 0.32 & 0.37 & 0.25 & 0.39 & 0.33 \\ 0.35 & 0.35 & 0.79 & 0.42 & 0.21 & 0.92 & 0.96 & 0.89 & 0.94 & 0.56 & 0.23 & 0.52 \\ 0.23 & 0.71 & 0.42 & 0.26 & 0.82 & 0.32 & 0.38 & 0.84 & 0.68 & 0.32 & 0.47 & 0.57 \\ 0.55 & 0.34 & 0.31 & 0.84 & 0.35 & 0.36 & 0.33 & 0.34 & 0.21 & 0.65 & 0.72 & 0.95 \\ 0.21 & 0.23 & 0.54 & 0.36 & 0.36 & 0.32 & 0.42 & 0.39 & 0.68 & 0.76 & 0.88 & 0.38 \\ 0.91 & 0.31 & 0.44 & 0.66 & 0.54 & 0.37 & 0.64 & 0.72 & 0.35 & 0.45 & 0.92 & 0.44 \\ 0.56 & 0.59 & 0.21 & 0.52 & 0.35 & 0.87 & 0.71 & 0.69 & 0.91 & 0.68 & 0.36 & 0.37 \\ 0.61 & 0.39 & 0.80 & 0.90 & 0.24 & 0.81 & 0.38 & 0.74 & 0.34 & 0.94 & 0.52 & 0.38 \end{bmatrix}$$

For instance, the value of feeder 2 is 0.92 since its feed the very critical loads (e.g. hospital) and 0.64 for feeder 3 as its feed the pump station and the other value as 0.35 for feeder 8 that its feed the non-critical load as shown in **Fig.7.**

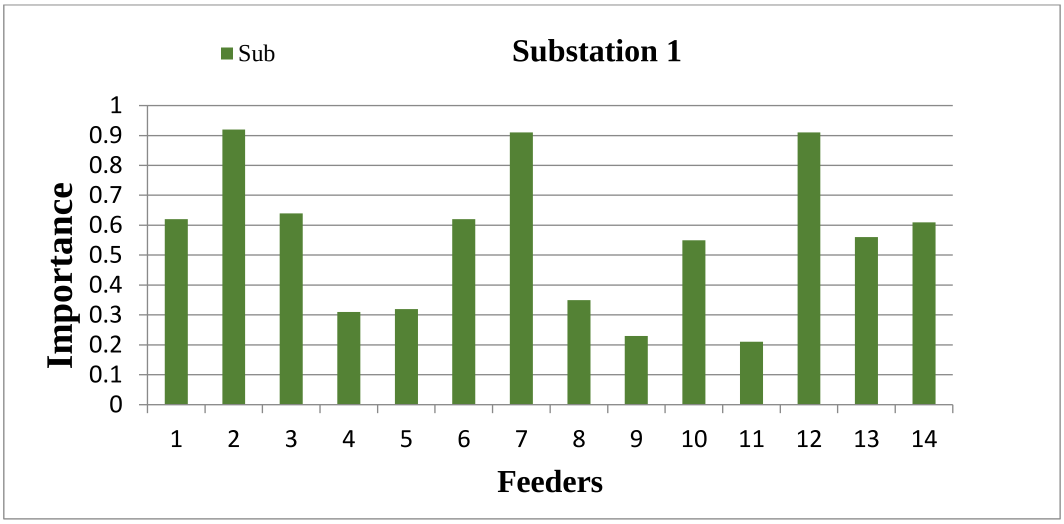

Figure 7. Importance for 14 Feeders Connected to the First Substation

The obtained simulation results showed that the loads with the lowest importance at the instant of LS within each category are selected for shedding as shown in the **Fig.1**. Therefore, those critical loads in every feeder in the substation are kept continuous operation and non-critical loads which are not so important are shed to zero in the new LM as shown:

$$LM = \begin{bmatrix} 5.5 & 2.6 & 3.1 & 0.0 & 3.3 & 5.0 & 0.0 & 2.2 & 0.0 & 2.8 & 0.0 & 2.0 \\ 3.2 & 0.0 & 0.0 & 0.0 & 2.7 & 4.7 & 3.7 & 0.0 & 3.0 & 4.0 & 3.3 & 0.0 \\ 3.0 & 4.0 & 5.2 & 2.5 & 0.0 & 3.1 & 2.2 & 4.4 & 4.1 & 5.5 & 2.1 & 0.0 \\ 0.0 & 2.5 & 0.0 & 3.3 & 5.5 & 2.9 & 0.0 & 2.0 & 2.7 & 3.2 & 0.0 & 4.0 \\ 0.0 & 5.3 & 2.5 & 0.0 & 4.4 & 0.0 & 3.1 & 5.5 & 3.1 & 4.8 & 2.4 & 2.0 \\ 3.1 & 0.0 & 3.9 & 4.5 & 5.2 & 0.0 & 5.0 & 2.3 & 4.4 & 3.5 & 5.1 & 2.0 \\ 4.2 & 4.5 & 0.0 & 0.0 & 2.5 & 3.6 & 2.5 & 0.0 & 2.4 & 0.0 & 3.2 & 0.0 \\ 0.0 & 0.0 & 4.6 & 3.2 & 0.0 & 2.1 & 5.4 & 3.1 & 4.1 & 3.3 & 0.0 & 4.2 \\ 0.0 & 4.8 & 3.2 & 2.1 & 3.6 & 0.0 & 4.4 & 3.9 & 2.0 & 0.0 & 2.2 & 3.5 \\ 3.9 & 0.0 & 0.0 & 4.3 & 0.0 & 3.0 & 0.0 & 0.0 & 0.0 & 2.0 & 3.2 & 5.1 \\ 0.0 & 0.0 & 5.3 & 2.8 & 2.5 & 0.0 & 3.8 & 5.3 & 3.6 & 5.1 & 4.5 & 3.9 \\ 2.3 & 0.0 & 4.6 & 5.2 & 3.9 & 4.7 & 5.1 & 2.6 & 5.0 & 2.7 & 4.6 & 2.1 \\ 4.0 & 2.0 & 0.0 & 3.9 & 0.0 & 5.2 & 4.2 & 4.7 & 5.0 & 3.6 & 2.3 & 4.8 \\ 5.2 & 5.3 & 2.6 & 4.7 & 0.0 & 3.6 & 4.1 & 2.2 & 0.0 & 5.5 & 3.6 & 4.0 \end{bmatrix}$$

For example, the residential load a_{41} in LM consumes 4.9 MW has $\propto_{41}$ is 0.31 importance in IM, so that under contingency conditions overloading, a_{41} is shed to 0.0 MW that shown in **Fig.8**.

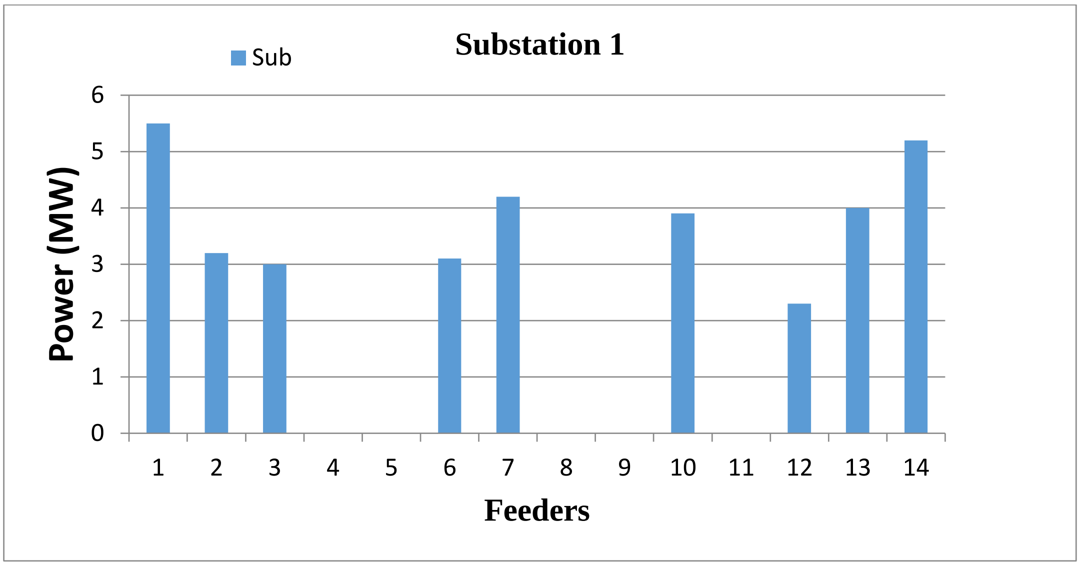

Figure 8. Practical Loads After Shedding Feeders (4-5-8-9-11)

Therefore, the total load of the grid after shedding will be 447.5 MW, which is lower than the supply power that is 450 MW. We can see that the feeders (4-5-8-9-11) are switching off (i.e. Their values 0 MW) because they have a low importance factor. The aforementioned 4 feeders will be under shedding from the substation 1 in order to investigate the balance between the demands - supply power.

4.2. Load shedding based on importance with wind energy resource connected to the network

The proposed impact integration wind energy on the power systems has been simulated using Power System Simulator for Engineer (PSS/E) software Version 30.3 applied to the Iraqi grid system. In this paper, it has been suggested wind farms include the following: Shaikh Saad and Al-Djal wind farms are located in the city of Wasit-Iraq, every wind farm location is assumed to have height is 100 m. of the selected model. However, the average output power of a wind generator over the year can be seen in the **Table. 3**.

Table 3. Average output power of wind generator per year.

Month	Shaikh Saad (MW)	Al-Dujaili (MW)	Total MW
Jan.	35.188	29.020	64.208
Feb.	44.680	37.701	82.381
Mar.	56.730	48.836	105.566
Apr.	19.568	14.898	34.466

Ma.	66.247	57.697	123.945
Jun.	51.785	44.041	95.826
Jul.	109.635	94.176	203.812
Aug.	66.247	57.455	123.702
Sep.	83.059	73.455	156.514
Oct.	30.595	24.859	55.455
Nov.	28.847	23.129	51.977
Dec.	41.529	34.808	76.338

It should be noted from the table here that the maximum output of the generation in July due to the variability of the wind speed at this time maximum as shown in **Fig.9.**

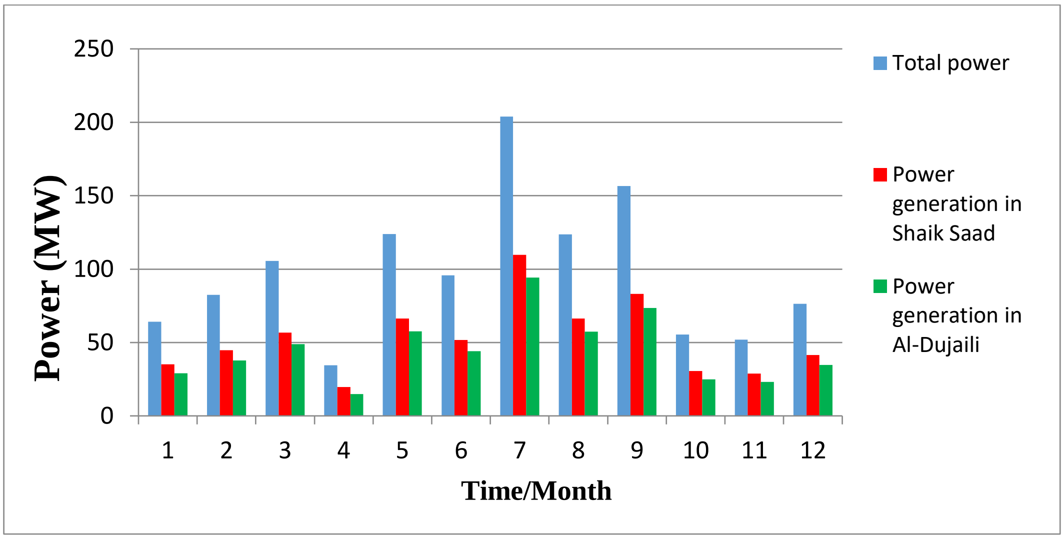

Figure 9. Output power of wind generator in Shaikh Saad and in Al-Dujaili region.

To achieve air gap between supply-demand power minimizing extremely, the rapid development of renewable energy is necessary, especially WP integration with the power system in order to achieve an additional capacity of generation. It is evident from **Fig.10** that, within the integration of wind generators to the system, the gap between the supply and demand power is minimized as much as possible.

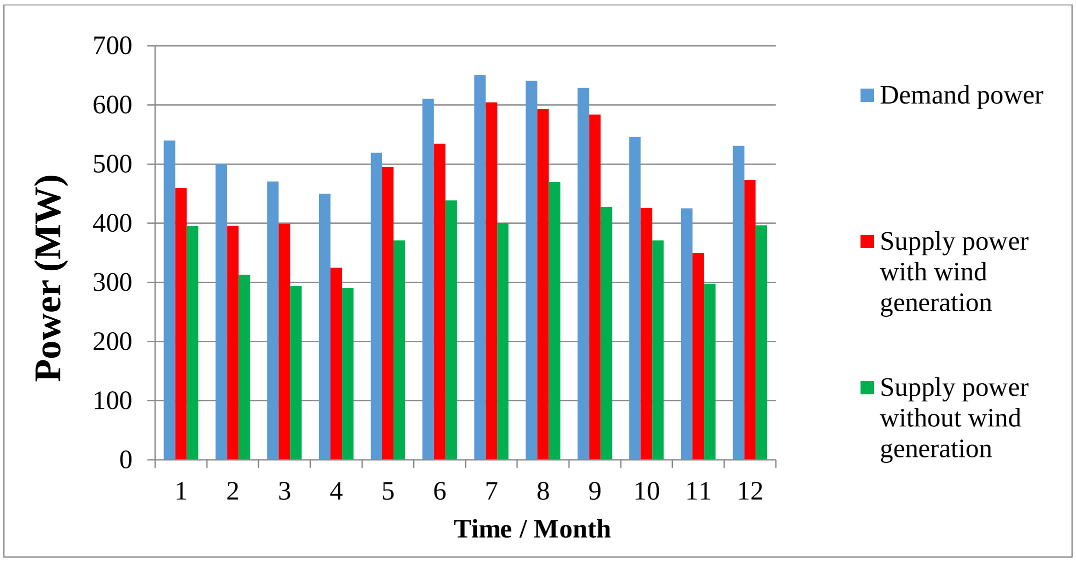

Figure 10. Output power generation with and without wind power.

The maximum demand power inquired at July month reach to 650.363 MW, and the power generation is 400.624 MW without the contribution of WP so with its 604.436 MW. In addition, it is known from **Fig.10** that the total LS quantity of the proposed scheme is minimal.
It seems that, by these integrations of wind generators to the power system, the LS scheme alerts and the amount of loads that should be shed from the feeders are reduced.
In order to clarify the variation on the amount of LS with the penetration of WP and without it that can be shown in **Fig.11**.

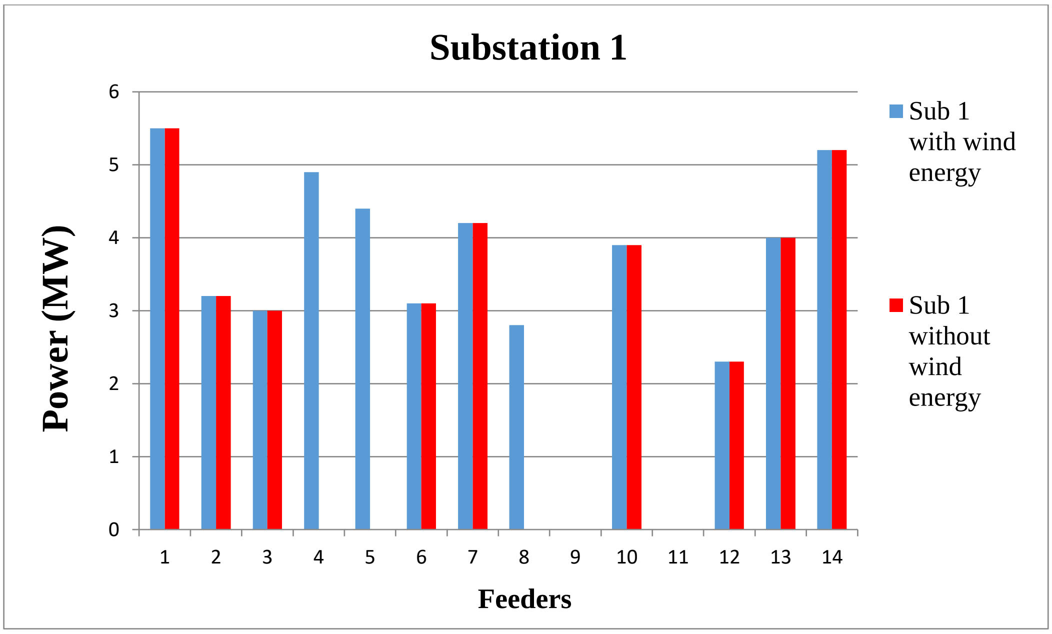

Figure 11. Practical loads after shedding feeders with and without a wind energy source.

Under disturbance condition such as overloading, the gap between supply and load is small value due to this contribution and the system will be operating without collapsing. Furthermore, the strategy has to reduce the load anywhere in the LM that has low priority in order to recover high priority loads with the continuous supply. In addition, from **Fig.11** the red feeders (4-5-8-9-11) at the first substation are switching off as shown in **Fig.8** and their values will be 0 MW. But the blue feeders (9-11) are only being reduced from the first substation when incorporating wind generators with the network. However, it is also important to see that only two feeders are being shed and the other three feeders are supplied due to the penetration of WP. Furthermore, the severity of demand-supply power unbalance on the critical load will be alleviated gradually through integrate of WP during the LS period and the process of LS scheme is based on PDs. **Table 4** condenses the comparison of the LS scheme with the wind generators that are jointed to the network of the power system and without them.

Table 4 Load shedding scheme based on PDs at the substation with and without wind power generation.

Sub. No.	Power demand for Sub.	Power demand for Sub. After LS		Load shedding based PDs at each Sub.		Feeders number being reduced	
		Without WP	With WP	Without WP	With WP	Without WP	With WP
1	56.3	34.4	46.5	21.9	9.8	4, 5, 8, 9, 11	9, 11
2	54.7	25.7	48.8	29	5.9	2, 6, 8, 10, 11, 12	6, 11
3	54.9	35	45.1	19.9	9.8	2, 4, 7, 10, 13	2, 13
4	55.7	31.6	51.8	24.1	3.9	1, 2, 5, 7, 9	5
5	54.2	25.1	45.1	29.1	9.1	3, 8, 10, 13, 14	8, 14
6	54.9	30.2	54.9	24.7	0.0	5, 6, 9, 11	….....
7	58.7	40.4	58.7	18.3	0.0	1, 4, 10	…….
8	53.4	33.9	53.4	19.5	0.0	2, 7, 10	……..
9	52.8	27.9	48.9	24.9	3.9	1, 10, 14	10

10	55.5	46	55.5	9.5	0.0	7,9	……..
11	49	34.2	41.5	14.8	7.5	1, 4, 8	1, 8
12	49.7	32.8	49.7	16.9	0.0	2, 3, 7	……..
Total power	649.8	397.2	599.9	252.6	49.9		

It is apparent that, with the incorporation of wind generators to the network, the LS scheme alters and reduces the amount of load to be disconnected from the substation. The penetration of WP creates desirable effects on the power system by providing supplementary system generation capacity during disturbance conditions. However, when this contribution of WP generation is obsoleted, the system is suffering from the over shedding of non-critical loads and unbalance supply-demand power. As it can be seen from **Table 4**, the feeders in the network are picked based PDs using **Table 1** to disconnect the established amount of demand. In this scheme, feeder with critical load (i.e. Hospital, given very high importance) represents high importance feeders in the network which are excepted from LS. For example, the LS location at substation 1 with a LS amount of 21.9 MW without considering WP and with it a LS amount of 9.8 MW. It should be noted that the results obviously show that the LS at all substations mend appreciably and one important factor in minimizing the impact of LS on the system is to have wind generators connected to the network of the power system.

5. CONCLUSION

We presented a LS process that takes place at the feeder's level based on their importance. Feeders will be disconnected according to the criticality of the demands. Consequently, low priority feeders are switched off along with the attached noncritical loads so as to minify the shedding influence on the critical loads. In this paper, the proposed LS scheme considering the penetration of WP generation in the power system. The results have been shown that high contribution of WP generation can have a large influence on the system during contingency conditions. The impacts of the absence of this contribution during LS on the power system can be a large amount of LS and unreliable for critical loads. The higher PDs are fed with a reliable power source with the penetration of wind generation by the real-time monitoring of the network accompanied with power reducing for the lower PDs.

Processes of the LS scheme according to implementing IM and LM, resulting in new LM is represented the practical new loads with shedding low PDs to investigate supply-demand balancing. In addition, this reduction is higher for non-critical loads and low or not exists for critical loads in order to maintain the operation of the important loads to the maximum extension possible. The tested sample is employed in the Iraqi national grid (ING) control center in Baghdad.

The main contribution of this paper is to sustain power for higher important loads where possible, and accurate load shedding amount while keeping the load under the identified power threshold. In this case, the critical loads such as health care and security installation are kept intact without any interruption as possible. The result of the implementation shows the effectiveness of the proposed load reducing scheme, as well as the logarithmic IM and LM. Moreover, in order to determine the LS capacity of each feeder based on the PDs, the shedding can be distributed between all the non-critical loads to achieve an effective process and improve the reliability for essential and unessential loads.

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NOMENCLATURE

LS = load shedding.
WP = wind power.
PDs = priority demands .
LM = load matrix.
IM = importance matrix.
α = importance factor.
P_T = mechanical output power
ρ = air density (kg/m^3)
C_p = power coefficien
A_T = rotor swept and recovered area of the wind turbine blades in (m2)
r_T = blade radius (m)
V_w, R = rated wind speed (m/s).
β = pitch angle
λ_T = corresponds to the optimal tip-speed ratio (TSR