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Research Article

Performance Improving of Grid Connected Photovoltaic System with Grid Contain Heavily Outages

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Abstract

The ability of grid connected PV system to export power is dependent on the availability of the distribution or transmission network, when the grid get outage there is no exported power if there is sufficient solar radiation that due to the anti-islanding protection technic of the solar inverters. This work proposed to implement the PV system within micro-grid in order to improve its performance which is large effected by the heavily outages due to load separation policy that followed to reduce the demand during most year months in Karbala city which is taken as case study, MATLAB software is used to implement all required algorithms. The obtained results show that the proposed microgrid improved the performance of the PV system by keeping approximately same yield that obtained with normal grid and reducing the amount of imported energy from the grid as well the local generators of the selected microgrid by large amount which confirms the success of this system.

Keywords*: PV System, Grid outages, Performance improved, micro-grid, energy management system.*

1. Introduction

Grid connected PV systems in the world account for about 99% of the installed capacity of solar energy compared to stand alone systems, which use batteries. Battery-less grid connected PV are cost effective and require less maintenance (J Sreedevi, *et al*, 2016). Normally, grid-tied solar PV power plants operate synchronized with the grid (K. Premkumar, *et al*, 2014), and shut-off immediately in case of failure of the grid to prevent back feeding electricity into de-energized power lines that may have fallen or that line crew members may be working on, also this shut down is important for safety of equipment (Bohan Liu, *et al*, 2016). The viability of grid connection of the PV system is depending on grid capacity, proximity and availability, (International Finance Corporation, 2015), the grid availability describes the percentage of time that the network is able to export power from the solar PV plant. The annual energy yield from a plant may be significantly reduced if the grid has significant downtime. This may have adverse effects on the economics of the project.

Today, all the world begins use the on grid PV system in very large scales as non-fossil energy source, numerous publications regarding deals with improving of PV system by implementing of energy storage system as well as microgrid, from this research: (David Velasco de la Fuente, *et al*, 2013) presents the analysis, design, and experimentation results of a PV energy management system with battery backup, the proposed system is capable of both grid-connected and islanded operations modes, (K. Premkumar, *et al*, 2014) aims at modeling grid-connected solar PV systems with and without energy storage, and compare the energy generation in a typical Indian scenario, (N. Alsayyed *et al*, 2016) specifies the goals of power resiliency and explains the reasons that most distributed PV systems as installed today in the US are technically incapable of providing consumer power during a grid outage, (D. Munteanu *et al,* 2017) is aiming to improve the dynamic response of PV systems in microgrids by using supercapacitors in order to obtain an improved stability for the entire power system and (H. Du Plooy, *et al* 2017) aims to improve the unstable power output responses of a renewable energy microgrid by designing and analysing storage strategies intended at power wavering compensation which solely consists of battery/generator and capacitive energy storage.

This work aims to improve the performance of 1MW PV system under Iraq climate and electrical grid condition with Karbala city (105 Km in the south-west of the capital Baghdad) as a case study. Often, in most of the Iraqi cities, there is a wide gap between the generation and demand in most year's months which for Karbala city is shown Fig.1. Load separations are

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usually used for most feeders in order to solve this problem.

Fig.1 Annually supplied and required powers for Karbala city from 2001 to 2016. (Karbala Electricity Distribution Directorate, 2017)

Therefore, implemented of grid connected PV system with grid has several outages reduce the yield of the plant too much which effect to the economics of the project. The solution that suggested to increase PV system performance in this study is by implemented the PV plant within a Micro-Grid, which can be implemented in different sizes, any place and any voltage level.

2. Micro-Grid structure and operation

Micro-grid (MG) is a small entity of electrical network which comprises of various Distributed Generation (DG) sources, storage devices, and group of loads in various classes. MG provides reliable and secure energy supply to the critical loads of communities while operating either in on-grid or off-grid mode (Arangarajan Vinayagam, *et al*, 2017). The operation of a MG offers distinct advantages to customers and utilities, i.e., improved energy efficiency, reduced environmental impact, and greater reliability. One of the most important features of MG is that they can independently operate in islanded mode without connection to the distribution system when power system faults or blackouts occur (David Velasco de la Fuente, *et al*, 2013). Fig.2 shows the typical configuration of AC micro-grid. (Seong-Su Shin, *et al*, 2016).

The balance between supply and demand of power is one of the most important requirements of MG management. In the grid-interconnected operation mode, the MG exchanges power to an interconnected grid to meet the balance (Jong-Yul Kim, *et al,* 2010). On the other hand, in off-grid mode, all the DG sources should be responsible for ensuring power balance and also regulation of voltage and frequency level in MG network through active coordinated power management and power sharing control strategies, in case that any mismatch between the generation and demand causes deviation in the voltage and frequency level which creates a negative influence on the quality of energy supply, thus affecting the performance of sensitive loads connected in the MG network (Arangarajan Vinayagam, *et al*, 2017).

Fig.2 The configurations of AC micro-grid.

3. Data required

In order to estimate the PV Plant power generation, the solar radiation and average daytime temperatures data are required, mathematical model are used to estimate the solar radiation data which modeling from equation (1) to equation (11) that studied in (Afaneen A. Abbood, *et al*, 2017) using MATLAB software according to the flowchart shown in Fig.3, the obtained results of solar radiation for horizontal surface are compared with other solar data from Photovoltaic Geographical Information System (PVGIS) and NASA Surface meteorology and Solar Energy data. The result in Fig.4 shows that PVGIS has relatively higher average than the others because its data don't include climate conditions (cloud, dust etc.), while NASA data has lower average radiation because it takes the effect of climate conditions and it seem alike with calculated data. Therefore, these empirical formulas can be dependent in this work because of corresponding the results with PVGIS and NASA data.

Fig.3 Flowchart for calculation the solar radiation

Fig.4 Monthly average solar radiation comparison

From Iraqi meteorological organization and seismology, the monthly average daytime temperatures for Karbala city in 2016 are obtained as shown in atable.1.

4. Micro-grid case study

Imam Hassan visitors' city has been selected as a case study for design of micro-grid. The city is just 17 Km south of Karbala city center on an area of 22 Acres which is used as a rest for travelers.

Imam Hassan visitors' city is supplied with electricity from the national grid by two 11kV underground cables with length of 22 Km though Ring Main Unit (RMU). Also, the city contains four diesel generators with 1 MVA rating 11 kV, 50 Hz, coupled with the grid feeders through another RMU. Later, the loads are fed from six transformers with rating of 1 MVA each one contains RMU, the control system of the city controls the four generators to operate in synchronously with the grid and in isolated mode.

The load profile of the case study MG in 2016 is shown in Fig.5, two sampling days are chosen to give an idea about the cut-off hours per day for every month, also its found that there are six months have twelve hours in which the grid is off per day, three with 6-8 hours per day and three with no grid outage hours.

Table.1 Monthly mean daytime temperature

Month	Jan	Fab	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temp. (°C).	10	14	18	24	30	35	37	38	31	25	15	9

4.1 Proposed system configuration

The proposed microgrid is subject to operate in isolated and grid-connected operation mode as it shown in Fig.6.

Fig.5 Power imported from grid for the visitor city in 2016. (a) January, (b) August (Karbala Electricity Distribution Directorate, 2017)

The microgrid is connected to 11KV 50Hz grid which represented the primary source of power fed the microgrid, Solar PV plant with 1012 kW_{DC} is considered to inject the available power into the MG during the daytime with properties shown in table.2.

Table.2 Solar PV plant properties

Item	Specific
Size	1012kWp (DC)
Penal Mounting type	Fixed
Tilt angle	32°
Module size, type and efficiency	275Wp, Poly, 16.8%
Number of modules per string	23
Number of strings in parallel	160
Total number of solar modules	3680
Number of inverters	One inverter

Battery energy storage system (BESS) which consists of a Lead-acid battery bank connected to the grid through a three-phase bi-directional voltage sourced converter (VSC) and connected to the MG through 0.4/11KV 400KVA transformer. BESS is capable of operating as either source or sink of power. BESS is dispatched to smooth the power fluctuations in system caused by PV plant with loads during standalone operation mode, BESS operates either in inverting or rectifying modes depending on the power management strategy. The diesel plant contains four diesel generators with 1 MVA rating 11 KV 50 Hz coupled with the grid feeders through RMU, one or more generator can be operated (during grid outage time

and if the PV and BESS are failure to cover the load) according to the demand at that time. MG load consists of six feeders each one is fed through 11/0.4KV 1MVA transformer.

As shown in Fig.6, there exist four agents in MG, namely, unit agents, generation agent, load agent, and main agent. Generation agent is assigned to receive and/or send the data from/to DG unit agents through the communication channel indicated by dotted black line. Each DG unit agent collects the local information such as DG breaker status, output voltage and current. In BESS, unit agent calculates state of charge (SOC) of battery and sends it to generation agent.

All these information is gathered in generation agent and then sent to the main agent. Local agents also generate and compute the feedback signals required for the internal controllers (red dotted lines) such as current or power loops, governor, and excitation controllers. Load agent also registers the status of load breakers and the power which is flown in each feeder. These data are sent to the main agent to inform the operator about the system states (dotted blue lines). This system is comparable in operation and control with that present in (Sam Koohi-Kamali, *et al*, 2014), but implemented with more one diesel generators.

4.2 Energy storage system (ESS) sizing

Renewable resources such as wind and solar PV are naturally intermittent and hence energy storage systems (ESSs) like battery can be exploited together with them to compensate for this drawback (Sam Koohi-Kamali, *et al,* 2014).

Several strategies can be considered when sizing energy storage system; peak demand reduction, energy harvesting to reduce export, mitigating intermittent grid outages, and standalone operation. Each strategy has differing demand on energy storage sizing and economic constraints (Lasantha Gunaruwan Meegahapola, *et al*, 2014). In this study, the storage system size was decided according to the standalone operation during there is sufficient solar radiation in order to get stable operation through export/import the energy to/from the BESS when the microgrid load is less/greater than the solar PV generation at this instant and to reduce the need to run diesel generators. This can be obtained by comparison the load demand with PV generation power at the time that is need the system to be operated in standalone with PV and BESS only. The power output from the PV system (P_{PV}) is expressed as: (Chaouki Ghena, *et al*, 2017).

$$P_{PV} = P_{PV.STC} f_{PV} \left(\frac{G}{G_{STC}}\right) [1 + \alpha_P (T_c - T_{c.STC})] \quad (1)$$

Where;
$P_{PV,\ STC}$: power output under standard test conditions (STC),
G: current irradiance,
G_{STC}: irradiance under STC, (1000W/m^2)
f_{PV}: PV derate factor, is the power reduction due to soling of the panels, wiring losses, mismatch, inverter and transformer efficiency, which are set equal to 2%, 1%, 2%, 1.3% and 0.6% respectively
α_P: temperature coefficient of the power,
$T_{c;}$ PV module temperature (˚C).
$T_{c,\ STC}$; PV module temperature under STC, $Tc_{,\ STC}$ =25°C.
The model temperature is calculated using the following relations: (Mahmoud Hammada, et al, 2015)

$$T_c = 20.4 + 1.2 \times T_{avg} \quad (2)$$

Where;
T_{avg}: average daytime temperature (˚C).

The charge or the discharge power into or out of the battery is regulated by the output power from the generation system (grid, PV and Diesel) and the load demand at a given time, at any given hour the battery state of charge (SOC) is expressed as follows: (Chaouki Ghena, *et al*, 2017).

$$SOC(t) = SOC(0) + \eta_c \sum_{k=0}^{t} P_c(k) + \eta_d \sum_{k=0}^{t} P_d(k) \quad (3)$$

Where;
SOC (0); initial SOC of the battery,
P_c; charged power,
P_d; discharged power,
η_c; charging efficiency,
η_d; discharging efficiency

4.3 Energy management program

MATLAB software was performed for the proposed MG power management control strategies and had been developed for on-grid and off-grid mode of operation. Fig.7 shows the battery charging /discharging control as well as energy management system (EMS). The stricture of the MATLAB program is as following:

- **Grid connected operation mode:** On-grid power management includes PV power management, battery power management with inclusion of battery SOC control, during on-grid mode, grid source act as a main power source which buffers any deficit or excess power generation in the MG network, the PV system is allowed to operate at maximum power generation while the battery power management is responsible to charge the battery system if SOC ≤ 90% in order to use it during islanded operation mode.
- **Off-grid operation mode:** In off-grid mode (islanding), PV inverter unit is operating as voltage source which provides active and reactive power support according to the voltage and frequency level in MG network. BESS provides active and reactive power support according to power generation level of PV and power demand in MG network. Therefore, power management in off-grid mainly involves the battery power management

with inclusion of SOC control in addition of diesel generators. In off-grid operation mode, the main signal for the charging and discharging control algorithm is the SOC. In order to protect the battery from deep discharging and overcharging, the battery SOC will be regulated between 45 and 90%. Based on the desired conditions, the EMS program for off-grid mode is built on the following cases:

- **If $P_{PV}>P_{load}$ & SOC < SOC_{max}**

  In this case the MG load is fed from the PV generation and the excess power is fed to the bidirectional converter in order to charge the batteries, make sure that the SOC not exceeds the SOC_{max}.

- **If $P_{PV}>P_{load}$ & SOC ≥ SOC_{max}**

  In this case, the MG load is fed from the PV generation but the exceeding power does not feed to the BESS, the system may be process to export power if there is another available load or Halt.

- **If $P_{PV}<P_{load}$ & $P_{PV}>0$& SOC > SOC_{min}**

  In this case of operation, the two inverters are share the power to feed the MG demand until they are unable to cover this demand, then one or more (according to the demand) diesel generators will feed the load with active and reactive power and the exceed power will be used to charge the batteries.

- **If $P_{PV}=0$ & P_{load} ≤P_{DG} & SOC < SOC_{max}**

  This case of operation occur during no solar radiation in which PV inverter is turn off, one diesel generator will be used to cover the demand and if there is unexceeding power, it will be used to charge the batteries.

- **If $P_{PV}=0$ & P_{load}≥ 800kW & SOC ≥ SOC_{min}**

  Also, this case of operation occurs during no solar radiation, according to MG demand and the available battery power at this instant; if the BESS can be share the load demand with one generator then no need to operate other diesel generator, else, two or more generators will be operated and the BESS will be charge/discharge according to load conditions

5. Results and discussion

The main goal of this work is study the performance of the PV system within the microgrid taking in account both the normal operation of the grid, and the actual operation of the grid considering the several outages due to load separation policy. The effect of grid outages on the performance of the grid connected PV system is showing in Fig.8 with grid outages time that most dependent in Karbala city is taken from table.3, the result shows that the reduction in PV energy that exported to grid exceeds 60% for four months as shown in Fig.8-b with annual average reduction of 43.21%.

Fig.7 proposed energy management MATLAB program

Fig.8 Effect of grid outages on the yield of the grid connected PV system

5.1 Sizing of energy storage system

Standalone operation of micro grid and economic constraints were considered to size the energy storage system, the expected demand profile of the selected micro-grid is plotted against the solar-PV generation using equation (1) which is assist in establishing energy storage system, according to the difference between the MG demand and PV generation which for January & August are shown in Fig.9, the ESS is set in which the bidirectional inverter is start to fed battery power when the difference equal to 300kW at this time the MG demand is fed from the PV and ESS only if the grid is unavailable, so with 300 kWh battery buck up and 50% DOD, the SOC is set between 45<SOC<90 to sure save operation of batteries, the total size will be 666 kWh which increased to 700 kWh in order to

compensate the losses of batteries and converters efficiency.

Fig.9 Expected demand of micro grid against 1MW PV plant generation (a) January, (b) August

5.2 Active power management of the proposed microgrid

After the application of the energy management program with flowchart shown in Fig.7, the active power management for the proposed system is implemented with 700 kWh ESS and load separation time cases that usually dependent in Karbala city which illustrated in table.3, 1 and 0 represented on and off state of grid respectively. Every month has different state according to the variation of the demand in that month, the states chosen in table.3 is according to the power readings for the visitor city.

For January, the two states S1&S2 are used in order to show the behavior of the proposed active power management at Fig.10 & Fig.11 respectively, the variations of MG load (kW), PV generation P_{pv} (kW) in (part-a)), battery state of charge (SOC (%)) in (part-b)), power taken from grid P_{grid} (kW) in (part-c)) and the power taken from the diesel generators in (part-d)). the MG load demand and PV power generation are taken as an average value for all month days, one-minute sampling is taken as step function in MATLAB m.file program to study this system.

Two hours on and two hours off are used in this month, when grid is off, one generator is operated as the load is below the maximum generator power, when the PV power is available with supporting of the ESS, the MG demand is covered if the grid is not available.

In off gird operation the MG is unable to export power, so when the battery SOC reaches to its maximum value while the MG demand is less than P_{pv}, the useful part of P_{pv} is equal to MG demand which represent in dotted brown line as it is clear in Fig.10 & Fig.11. The results show that the energy imported from grid and generators are reduce from (6683- 4606) kWh/day and (6684- 4355) kWh/day respectively.

Table.3 Load separation time states

State		S1	S2	S3	S4	S5
Time	1	1	1	0	1	1
	2	1	1	0	1	1
	3	1	0	1	1	1
	4	1	0	1	1	1
	5	1	1	0	1	1
	6	1	1	0	1	1
	7	1	0	1	1	1
	8	1	0	1	0	1
	9	1	1	0	0	1
	10	1	1	0	1	0
	11	1	0	1	1	0
	12	1	0	1	0	1
	13	1	1	0	0	1
	14	1	1	0	1	0
	15	1	0	1	1	0
	16	1	0	1	0	1
	17	1	1	0	0	1
	18	1	1	0	1	0
	19	1	0	1	1	0
	20	1	0	1	0	1
	21	1	1	0	0	1
	22	1	1	0	1	1
	23	1	0	1	1	1
	24	1	0	1	1	1
Used Month		3, 10, 11	1, 5, 6, 7, 8, 12	1, 5, 6, 7,8, 12	2, 4, 9	2, 4, 9

Fig.10 Active power management for January with S2

5.3 Energy saving and performance analysis of microgrid

From the obtained results, its very clear that the MG provides an excellent environment for the implementation of PV system regardless of the

additional cost that incurred by MG design. Fig.12-a shows the amount of the useful PV energy in average MWh/day for every month in three cases, ideal 1MW grid connected PV system with grid has no outages, 1MW grid connected PV system with Karbala grid and 1MW PV system implemented within the proposed MG.

Fig.11 Active power management for January with

Fig.12 The amount of the useful PV energy in three cases

Large amount of energy is saved in month contain load separation which reached to 185% and 177% in December and January months as appear in Fig.12-b in light blue bars, the annually average of increasing in PV power generation is 98.74% compared with grid connected PV system in grid contain these outages. Compared with ideal PV system the amount of reduction in PV energy (due to the energy loss in the inverter/charger and during the PV power is greater than MG demand while the ESS at its maximum value) appears as red bars in Fig.12-b with annually avarge of 3.619%.

Fig.13-a shows the amount of energy in (MWh/day) imported from grid with and without MG, this is mainly depended on how many hours that grid in available and the value of MG demand, maximum reduction in the importing of energy from grid is occur in March and October months with 48.45% and 43.9764% respectively with annually average reduction of 33.69% as it appears in Fig.13-b.

Fig.13 Energy imported from grid with and without MG

Fig.14 Diesel generators energy with and without MG

Other energy reduction is occur which is the energy imported from the diesel generators during off grid operating and the PV and ESS can insure save operation of MG, also during no PV power, when the load exceeds one generator rating, the exceeds will be fed from the ESS till the SOC reached to its minimum values, then the second generator is running in parallel with first one. Fig.14-a. shows the amount of MWh/day impored from generator(s) with and without MG, maximum reduction occurs in April with

58.68% reduction and the annually reduction is about 43.10% as shown in Fig.14-b. March, October and November are don't appear in this calculation because the electrical power from the grid is available in these months and no need to import energy from these generators.

Conclusions

Electrical grid outages due to the load separation represents the biggest obstacle in the implementation of grid connected PV systems which cause reduction about half plant yield led to reduce their success. Implementing the PV system within microgrid improved the performance of the system by keeping approximately same yield obtained in normal conditions and reducing the amount of imported energy from the grid as well the local generators for the microgrid by a large amount which confirms the success of this system.

References

J Sreedevi, Ashwin N, M Naini Raju, (2016), A Study on Grid Connected PV system, *IEEE, Power Systems Conference (NPSC)*,

K. Premkumar, Dr. Suresh K, (2014), Modeling grid-connected solar PV generator with and without energy storage, *University of Kerala, Applied Electronics and Instrumentation*, pp.1-5.

Bohan Liu, Xiangping Ni, Guozeng Yan, Bo Li, Ke Jia,(2016), Performance of ROCOF Protection in PV System*, IEEE, PES Asia-Pacific Power and Energy Conference* - Xi'an – China, pp.454-457.

International Finance Corporation, (2015), Utility-Scale Solar Photovoltaic Power Plants, a project developer's guide.

David Velasco de la Fuente, César L. Trujillo Rodríguez, Gabriel Garcerá, Emilio Figueres, Senior, and Rubén Ortega González (2013), Photovoltaic Power System With Battery Backup With Grid-Connection and Islanded Operation Capabilities" *IEEE*, VOL. 60, NO. 4, pp.1571-1581.

Nidal A. Alsayyed, Weihang. Zhu, (2016), Regulatory islanding parameters in battery based solar PV for electricity system resiliency" *IEEE,* Vol. 6, pp.1-11.

D. Munteanu, C. Marinescu, (2017), Improving the Dynamic Response of PV Systems in Microgrids by Using Supercapacitors" Optimization of Electrical and Electronic Equipment (OPTIM) & 2017 Intl Aegean Conference on Electrical Machines and Power Electronics (ACEMP), Brasov, Romania.

H. Du Plooy, M. Adonis, A. Raji, (2017), The Impact of Energy Storage on the Stability of Renewable energy in a Micro Grid, *IEEE*, Domestic Use of Energy (DUE), International Conference on, Cape Town, South Africa.

Iraqi ministry of electricity /Karbala Electricity Distribution Directorate/ operation and control Dept. (2017).

Arangarajan Vinayagam, K. S. V. Swarna, Sui Yang Khoo, Aman Than Oo, Alex Stojcevski, (2017), PV Based Microgrid with Grid-Support Grid-Forming Inverter Control-(Simulation and Analysis), *Smart Grid and Renewable Energy*, Vol.8, pp.1-30.

Seong-Su Shin, Joon-Seok Oh, Su-Hyeong Jang, Woo-Kyu Chae, Jong-Ho Park, Jae-Eon Kim (2016), A Fault Analysis on AC Microgrid with Distributed Generations", *Journal of Electrical Engineering Technology JEET*, Vol. 11(6), pp.1600-1609.

Jong-Yul Kim, Jin-Hong Jeon, Seul-Ki Kim, Changhee Cho, June Ho Park, Hak-Man Kim, Kee-Young Nam, (2010), Cooperative Control Strategy of Energy Storage System and Microsources for Stabilizing the Microgrid during Islanded Operation, *IEEE*, VOL. 25, NO. 12, pp.3037-3048.

Afaneen A. Abbood, Mohammed A. Salih, Hassan N. Muslim, (2017), Management of Electricity Peak Load for Residential Sector in Baghdad City by Using Solar Generation, *International Journal of Energy and Environment*, Vol 8, Issue 1, pp.63-72.

Sam Koohi-Kamali, N.A. Rahim, H. Mokhlis, (2014), Smart power management algorithm in microgrid consisting of photovoltaic, diesel, and battery storage plants considering variations in sunlight, temperature, and load, *Energy Conversion and Management*, Vol.84, pp.562–582.

Lasantha Gunaruwan Meegahapola, Duane Robinson, A. P. Agalgaonkar, S. Perera, P. Ciufo, (2014), Microgrids of Commercial Buildings: Strategies to Manage Mode Transfer From Grid Connected to Islanded Mode", *IEEE Transactions on sustainable energy*, pp.1-11,2014.

Chaouki Ghena, Tareq Salameh, Adel Merabet, Abdul Kadir Hamid, (2017), Modeling and Optimization of Hybrid Solar-Diesel-Battery Power System, IEEE, Modeling, Simulation, and Applied Optimization (ICMSAO), 7th International Conference, 4-6 April 2017, Sharjah, United Arab Emirates, pp.1-5.

Mahmoud Hammada, Munzer S. Y. Ebaidb, Ghassan Halaseha, Baslan Erekat, (2015), Large Scale Grid Connected (20MW) Photovoltaic System for Peak Load Shaving in Sahab Industrial District", *Jordan Journal of Mechanical and Industrial Engineering (JJMIE)*, Vol. 9, Issue 1, pp. 45–59.