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ARTICLE

Performance Assessment of Motorized Solar Photovoltaic Louvers System Using PVSYST Software

Hussein Safwat Hasan Hasan Humor Hwang*

Department of Information and Communications Engineering, Myongji University, Yongin, Gyeonggi-do 17058, Republic of Korea

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ABSTRACT

In the realm of technological market penetration of solar photovoltaic louvers (PVL) addressing environmental difficulties and the industrial revolution, a new avenue of renewable energy is introduced. Moreover, solar energy exploitation through building façades was addressed through motorized solar photovoltaic louvers (MPVL). On the other hand, proponents exalted the benefits of MPVL overlooking the typical analyses. In this communication, we attempted to perform a thorough industrial system evaluation of the MPVL. This communication presents a methodology to validate the industrial claims about MPVL devices and their economic efficiency and the insight on how geographical location influences their utilization and augment their potential benefits. This task is carried out by evaluating the extent of solar energy that can be harvested using solar photovoltaic system (PVSYST) software and investigating whether existing product claims are associated with MPVL are feasible in different locations. The performance and operational losses (temperature, internal network, power electronics) were evaluated. To design and assess the performance of different configurations based on the geographical analogy, simulation tools were successfully carried out based on different topographical locations. Based on these findings, various factors affect the employment of MPVL such as geographical and weather conditions, solar irradiation, and installation efficiency. tt is assumed that we successfully shed light and provided insights into the complexity associated with MPVL.

1. Introduction

As fossil fuel dependency over the years increased paralleled with its severe environmental consequences, alternative energy resources had received grave attention [1]. Most countries are considering solar energy as a primary candidate for harnessing alternative sources of energy. The overall energy that can be obtained from the sun is 1.8 x 10^{11} MW which is more than enough on the human required energy consumption [2]. These abundant clean energy can be directly harnessed through numerous techniques such as thermal and photovoltaic (PV) energy harvesting. Among these technological advances, PV is favored due to its propagation addressing the clean energy resource dilemma by utilizing abundant solar energy by directly capturing solar irradiation and converting it instantaneously to electrical energy. Currently, this technology is already industrially utilized providing clean

**Corresponding Author:*
Humor Hwang,
Department of Information and Communications Engineering, Myongji University, Yongin, Gyeonggi-do 17058, Republic of Korea;
Email: hmhwang@mju.ac.kr

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energy [3,4]. Likewise, technological advances regarding renewable energy are still in peril, recent evolution of smart devices transformed the traditional solar cells into a structural-functional segment through the incorporation of this technology into the louvers system. Considering the performance and aesthetics that consumers seek for their homes. The demand for advancement gives triggered the development of solar photovoltaic louvers (PVL) which serve as an energy harvesting system that simultaneously acts as a solar shading system. PVL acts like venetian blinds that block a compelling amount of solar radiation from entering the building's window reducing the cooling operating cost. The rising popularity of PVL applications can be attributed to their suitability for newly developed zero energy and zero-carbon building design, as well as their ability to help reach benchmarks defined by building energy labels [5,6].

Traditional PV is situated in a fixed angular stature concerning the sun's optimal irradiation but this design creates a shadowed area between the blind slits. This leads to a reduction in the PVL efficiency and its energy harvesting capability. Therefore, manipulation of the angular stature of the PVL considering the sun direction to harvest the optimal solar radiation is considered. Formative development was employed to progressively utilize the abundant solar irradiation through the incorporation of sun-tracking ability on PVL or motorized solar photovoltaic louvers (MPVL). The smaller dimension of PVL compared to the traditional PV system enables PVL the liberty to do the necessary angular movement to track the sun and gather the optimum energy at a given time. This will allow a maximal depth of inflow of solar light to the PV module [7,8].

Despite the progress made from a technology point of view, implementing MPVL remains non-trivial from a technical standpoint, and validating the claims regarding this technology is still imperative. Therefore, a need to provide standard analyses to quantify the total power generated from the MPVL systems with the optimized behaviors and functionality [5]. Economic advantage is often overlooked in cost analyses regarding the efficiency tradeoff of the proposed technology, energy generation requires significant investment in infrastructure and energy operating costs that could potentially not be recovered by insufficient power generation. Hence, an evaluation of solar MPVL electricity production and consumption was thoroughly scrutinized. Few would dispute this view, but the magnitudes of these effects have not been systematically quantified. The MPVL commercial product information in conjunction with the theoretical photovoltaic system analysis was thoroughly scrutinized to estimate the potential savings of this technology. In this paper, we use PVSYST software to assess the MPVL feasibility relative to the industrially available products [9]. The comparative power production of theoretical and commercial solar MPVL allows us to discuss the economics of solar MPVL power generating efficiency, with the consideration of operational factors such as the energy cost to drive the sun tracking ability of the system [10]. To clarify where this research fits in the debate, we presented the basic approach to valuing solar PVL power using PVSYST software to analyze the MPVL power generation. The economic feasibility and viability of MPVL solar harvesting implementation relative to geographical location were mainly aimed on the simulation. By analyzing the energy production, performance ratio, efficiency, and cost to determine the optimal location feasibility.

2. Experimental

Accurate simulation of the MPVL devices requires integrated energy simulation tools to properly evaluate and analyze the PVL electricity production. The methodology presented in this paper is a step up from the existing work that had applied a fully parametric PVL model to evaluate both daylighting and energy-related parameters to validate its flexibility for commercial or residential projects. The PVsyst simulation tool was used to validate the effect of geographical topology on energy harvesting efficiency. PVsyst is a simulation software was designed to calculate the necessary data for the operation of a PV system. This software provides the probable energy generation of a specified system which is used for the design and configuration of the PV system. The generated information is based on the scaled simulation which is highly influenced by the topology site of the PV system. Results may consist of several simulations variables that can be presented at monthly, daily, or hourly rates. The simulation can also predict the flaw in the design through system and collection losses [2]. The overall research goal is to provide a guide in building and applying PVL. The idea is to provide insights on the transcribed PVL limitations with the symmetrical features and attempt to maximize solar energy by system adopting the configuration from the combination of different geometrical locations.

3. Results and Discussion

3.1 Geographical and Location Correlation on Solar Energy Harvesting of MPVL

PV infrastructure become rampant these past few years as a part of the green energy transition. Progressive development of the PV system garnered the employment

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of MPVL intending to optimize the solar harvesting capability. This led to the design modification to track the sun through the angular movement of sectioned PV grid. This will allow optimum energy harvesting capability. And PVsyst software was utilized to determine the effectiveness of this advancement relative to topographical location. All figures were generated through the simulation measurements on three different locations. Demonstrated in Figure 1 is a visual representation of the simulation design. The panels are programmed to track the sun movement following the peak of solar radiation through single-axis orientation. It is well understood that the location greatly affects the power generation in terms of PV systems which is highly influenced by the location weather. This confirms the power harvesting feasibility of a certain location. In this research work, PVSYST software was used to simulate the energy harvesting capability of MPVL on different locations (Seoul, Cairo, and New York) in a daily setting in a year.

All the figures, tables are depicted here in the paper are generated during the simulation process. As this paper represents the computational modeling, we present our simulated results of a small system MPVL, all measurements are based on different scenarios at different cities Seoul, Cairo, and New York. Temporal efficiency and energy harvesting capacity of MPVL depending on the location variation can be realized [11]. The azimuth is varied from 0 to 90°, the incident solar energy radiation was tracked by the MPVL system ensuring a perpendicular sunlight projection. Modifying the azimuth angle any time of the day and month of the year. Due to the elliptical sun path on the celestial sphere, different solar heights can be observed at different locations on earth [12]. Evaluation of the power transmission capacity through PVSYST software is demonstrated. Shown in Figure 2 a-c is the sun path on different locations (Seoul, Cairo, and New York). The graph depicts the attenuation of solar light diffusivity with relative shading loss parametric relative to the angular orientation of the MPVL. It can be discerned that Cairo demonstrated a higher solar height followed by Seoul and lastly New York. This can be correlated to the locational advantage of Cairo being situated in the middle latitude of the equator. The solar path demonstrated the same trend in Cairo having wider solar attenuation, the wider asymptotic azimuthal projection starting from 10-14 h. On the other hand, Seoul demonstrated a narrower solar path which can be correlated to the lower sun height which leads to lower solar attenuation [8]. The solar path of New York was found to be the lowest among the three locations attributable to the reduction of radiation transmission and locational constraints [11]. To meteorological and incident energy of the investigated locations were elaborated through the interpretation of global horizontal irradiation (GlobHor) and diffuse irradiation (DiffHor) as presented in Tables 4, 8, and 12. Presenting the overall global incident energy (GlobHor and DiffHor) on the collection plane of Seoul (1,183 and 756 KWh/m^2), Cairo (1,891 and 826 KWh/m^2), and New York (1,429 and 677 KWh/m^2), confirming that Cairo has the highest incident energy compared to Seoul and New York. It can be concluded solar energy transmission and harvesting are highly dependent on location which gravely affects the utilization of MPVL in specific areas [5].

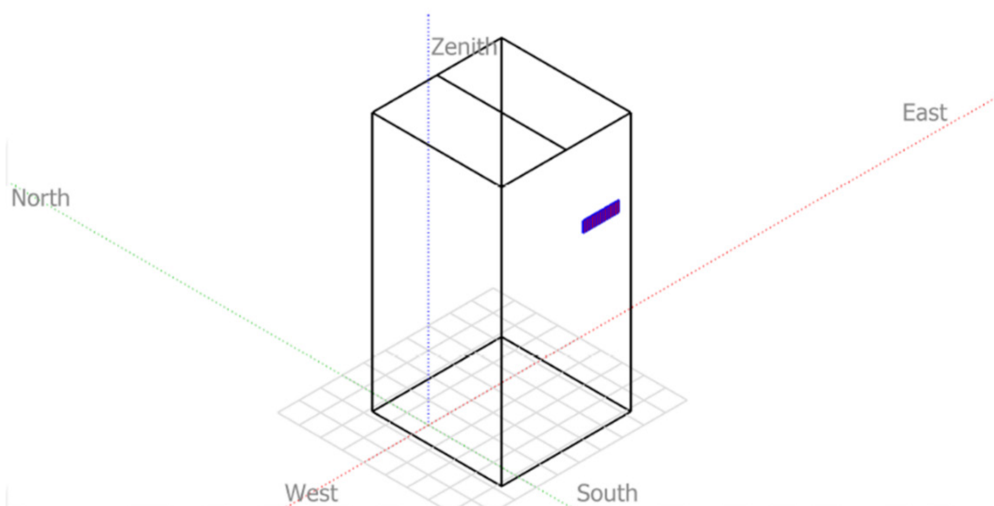

Figure 1. The perspective of the PV field and surrounding shading scene.

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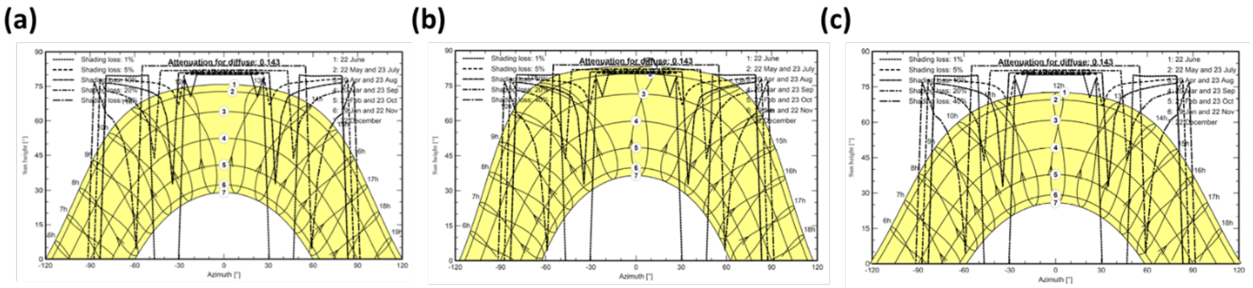

Figure 2. Sun path in (a) Seoul, (b) Cairo and (c) New York

3.2 Performance Analysis

It has been valued that onsite PV power generation offers an advantage through clean energy harvesting. The incremental modification had been developed infusing functionality on the PV system through seamless infusion on the existing infrastructure through MPVL. Like any other power-generating infrastructure, MPVL requires a significant amount of investment. Evaluation of the efficiency and economic advantage is imperative. Therefore, PVSYST software was utilized to build a systematic simulation. PVSYST software has been chosen due to its accuracy, simplistic operation, and diverse functions, it provides daylighting analysis, solar radiation, and harvesting performance. All the results presented are achieved through the design simulation. The simulation produces monthly data for one year. The setting for the analysis are as follows: tracking axis 0-90°, rotating phi limits -60-60°. Performance assessments of MPVL on different locations were thoroughly scrutinized. Comparison of the data sets simulated from three different locations has been conducted and summarized in Figure 3 a-f and Table 12. These data will serve as a representation of the actual installation of MPVL panels taking to account the fluctuation in the solar radiation [13]. This data is also particular on the losses and effect of orientation, operation, obstructions, and other factors that affect the efficiency of solar MPVL. The energy production has a monthly increment with substantial variation relative to geographical location as discussed earlier. Monthly energy production fluctuation is also observed reflecting the weather change throughout the year, with Cairo having the most linear yearly energy production accounting for the limited weather fluctuation in the area. Seoul has a sharp drop in energy yield in the middle of the year due to seasonal weather transitions. And New York has an almost plateau monthly energy output. The monthly trend influence the yearly power generation with Seoul having 1,704 kWh/year, Cairo 2,281 kWh/year, and New York 2,276 kWh/year. The performance ratio (PR) of the MPVL is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r) as referred on equation 1 [2]. It can be noticed that even though Cairo demonstrated a higher energy harvesting probability compared to New York based on the earlier assessment their yearly energy output is almost the same. Rendering a performance ratio of 0.578, 0.492, and 0.550 (Seoul, Cairo, and New York) in each location leaving Cairo the lowest energy conversion. This can be ascribed to the collection loss in Cairo due to the location's thermal effect disseminating a massive amount of energy during solar harvesting compromising the efficiency of the system. Even though Seoul was placed on the lower solar irradiation and yearly power generation among the three cities, it garnered the highest performance ratio due to its low energy collection loss. The two categories of PV energy losses are collection loss and system loss. The system losses are fairly average throughout the year and not influenced by the location, attributed to an anavoidabale system limitation of partial shading. On the other hand, collection loss affects the efficiency of the system the most which can be described as energy loss in wiring and voltage intolerance [14]. Influence by the month of the year and highly confide in the locational situation which can be ascribed on the effect of the regional weather conditions. The results shown in the tables for each location present the detailed calculation of energy production and variables that govern the energy losses.

$$PR = \frac{Y_f}{Y_r} \tag{1}$$

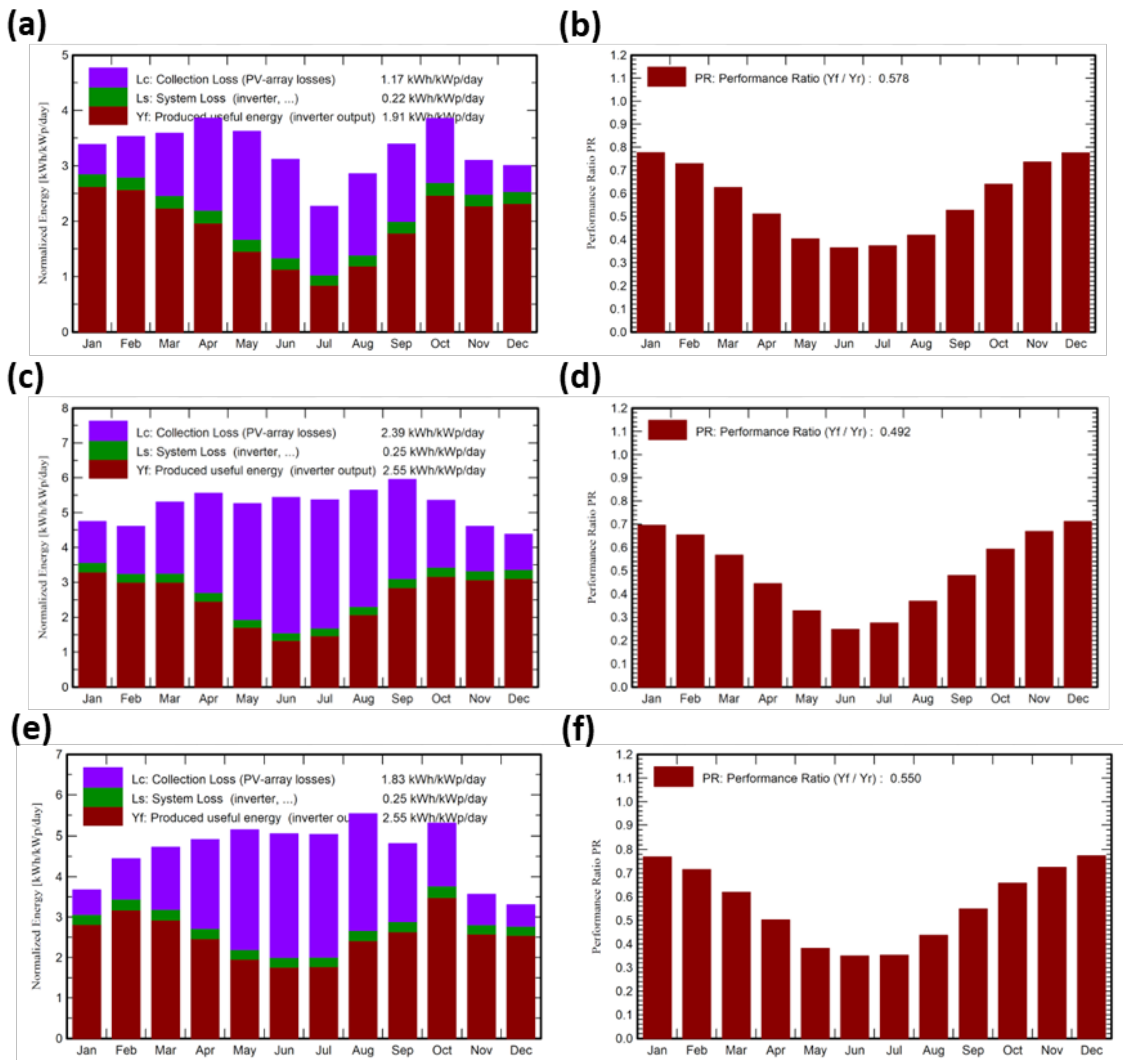

Figure 3. Monthly normalized energy production and performance ratio in (a-b)Seoul, (c-d) Cairo, and (e-f) New York.

Table 1. Normalized performance coefficients of MPVL system yielded in Seoul simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	3.39	0.525	2.86	0.231	2.63	0.155	0.068	0.777
February	3.53	0.727	2.80	0.229	2.57	0.206	0.065	0.729
March	3.58	1.118	2.47	0.224	2.24	0.312	0.063	0.626
April	3.86	1.661	2.20	0.227	1.97	0.430	0.059	0.511
May	3.62	1.947	1.68	0.216	1.46	0.537	0.060	0.403
June	3.11	1.771	1.34	0.207	1.14	0.569	0.067	0.365
July	2.27	1.235	1.03	0.186	0.85	0.545	0.082	0.373
August	2.85	1.459	1.39	0.199	1.20	0.511	0.070	0.419
September	3.39	1.397	2.00	0.210	1.79	0.412	0.062	0.527
October	3.86	1.154	2.70	0.233	2.47	0.299	0.060	0.640
November	3.10	0.607	2.49	0.211	2.28	0.196	0.068	0.736
December	3.00	0.460	2.54	0.214	2.33	0.153	0.071	0.775
Year	3.29	1.173	2.12	0.215	1.91	0.356	0.065	0.578

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Table 2. Meteo and incident energy of 1 M^2 PV system in Seoul.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²	DifS_GI ratio
January	62.6	34.84	-2.26	2.6	104.9	14.34	6.25	0.000
February	77.1	47.85	0.32	2.7	98.7	18.41	7.68	0.000
March	107.0	67.40	5.58	3.0	111.1	25.08	10.67	0.000
April	130.1	81.67	12.04	2.9	115.8	29.28	12.98	0.000
May	145.0	91.27	17.56	2.6	112.3	32.45	14.48	0.000
June	132.6	89.15	21.38	2.4	93.4	31.57	13.22	0.000
July	101.5	72.85	24.36	2.4	70.3	27.08	10.12	0.000
August	110.2	75.81	25.14	2.4	88.5	27.96	10.99	0.000
September	104.7	67.61	20.53	2.1	101.8	25.27	10.43	0.000
October	95.3	55.39	14.65	2.1	119.5	21.47	9.51	0.000
November	62.6	39.76	6.77	2.4	92.9	15.78	6.23	0.000
December	54.1	32.27	-0.07	2.5	93.0	13.32	5.40	0.000
Year	1183.0	755.88	12.23	2.5	1202.5	282.00	117.95	0.000

Table 3. Detailed system losses of the MPVL simulation in Seoul.

	ModQual kWh	MisLoss kWh	OhmLoss kWh	EArrMPP kWh	InvLoss kWh
January	-1.698	4.694	1.614	217.2	17.52
February	-1.499	4.145	1.223	192.0	15.68
March	-1.462	4.042	1.087	187.4	17.02
April	-1.261	3.487	0.805	161.7	16.70
May	-0.991	2.740	0.479	127.2	16.41
June	-0.768	2.124	0.314	98.7	15.25
July	-0.611	1.689	0.250	78.5	14.15
August	-0.825	2.281	0.438	105.9	15.08
September	-1.145	3.166	0.808	146.8	15.40
October	-1.604	4.434	1.460	205.3	17.71
November	-1.430	3.954	1.288	183.0	15.53
December	-1.508	4.169	1.383	193.0	16.27
Year	-14.803	40.925	11.148	1896.7	192.71

Table 4. Balances and main results of MPVL system yielded in Seoul simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	3.39	0.525	2.86	0.231	2.63	0.155	0.068	0.777
February	3.53	0.727	2.80	0.229	2.57	0.206	0.065	0.729
March	3.58	1.118	2.47	0.224	2.24	0.312	0.063	0.626
April	3.86	1.661	2.20	0.227	1.97	0.430	0.059	0.511
May	3.62	1.947	1.68	0.216	1.46	0.537	0.060	0.403
June	3.11	1.771	1.34	0.207	1.14	0.569	0.067	0.365
July	2.27	1.235	1.03	0.186	0.85	0.545	0.082	0.373
August	2.85	1.459	1.39	0.199	1.20	0.511	0.070	0.419
September	3.39	1.397	2.00	0.210	1.79	0.412	0.062	0.527
October	3.86	1.154	2.70	0.233	2.47	0.299	0.060	0.640
November	3.10	0.607	2.49	0.211	2.28	0.196	0.068	0.736
December	3.00	0.460	2.54	0.214	2.33	0.153	0.071	0.775
Year	3.29	1.173	2.12	0.215	1.91	0.356	0.065	0.578

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Table 5. Normalized performance coefficients of MPVL system yielded in Cairo simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	4.75	1.167	3.58	0.274	3.31	0.246	0.058	0.696
February	4.60	1.342	3.26	0.252	3.01	0.291	0.055	0.654
March	5.31	2.039	3.27	0.260	3.01	0.384	0.049	0.567
April	5.56	2.845	2.72	0.250	2.47	0.512	0.045	0.444
May	5.26	3.312	1.94	0.222	1.72	0.630	0.042	0.327
June	5.43	3.874	1.56	0.220	1.34	0.713	0.041	0.247
July	5.37	3.673	1.69	0.217	1.48	0.684	0.040	0.275
August	5.65	3.335	2.31	0.232	2.08	0.591	0.041	0.368
September	5.95	2.835	3.12	0.260	2.86	0.476	0.044	0.480
October	5.35	1.911	3.44	0.265	3.17	0.357	0.050	0.593
November	4.61	1.267	3.34	0.258	3.08	0.275	0.056	0.669
December	4.38	1.005	3.38	0.258	3.12	0.229	0.059	0.712
Year	5.19	2.389	2.80	0.247	2.55	0.461	0.048	0.492

Table 6. Meteo and incident energy of 1 M^2 PV system in Cairo.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²	DifS_GI ratio
January	94.6	44.65	14.06	3.5	147.2	18.22	9.46	0.000
February	106.7	58.95	15.73	3.7	128.9	22.13	10.65	0.000
March	157.7	74.60	18.86	4.2	164.5	26.89	15.74	0.000
April	186.7	85.05	21.89	4.3	166.9	28.85	18.65	0.000
May	213.8	92.53	26.09	4.2	162.9	30.11	21.34	0.000
June	219.4	86.03	28.40	4.0	163.0	27.92	21.92	0.000
July	220.1	83.33	29.84	3.6	166.4	27.31	21.97	0.000
August	200.9	83.85	29.93	3.5	175.1	28.30	20.06	0.000
September	170.2	68.40	27.75	3.6	178.5	24.78	17.01	0.000
October	135.9	61.55	24.76	3.4	165.8	23.38	13.57	0.000
November	98.4	45.13	19.95	3.0	138.2	18.11	9.82	0.000
December	86.8	41.71	15.97	3.3	135.8	16.95	8.64	0.000
Year	1891.3	825.79	22.81	3.7	1893.2	292.95	188.83	0.000

Table 7. Detailed system losses of the MPVL simulation in Cairo.

	ModQual kWh	MisLoss kWh	OhmLoss kWh	EArrMPP kWh	InvLoss kWh
January	-2.128	5.883	2.328	271.9	20.82
February	-1.749	4.835	1.586	223.8	17.30
March	-1.939	5.361	1.699	248.2	19.74
April	-1.558	4.306	1.061	199.7	18.35
May	-1.149	3.178	0.584	147.6	16.87
June	-0.893	2.468	0.368	114.7	16.18
July	-1.002	2.771	0.467	128.7	16.50
August	-1.369	3.785	0.848	175.6	17.62
September	-1.789	4.945	1.507	229.0	19.09
October	-2.042	5.646	2.060	261.1	20.14
November	-1.921	5.311	2.222	245.4	18.94
December	-2.007	5.549	2.288	256.4	19.57
Year	-19.546	54.037	17.017	2502.1	221.10

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Table 8. Balances and main results of MPVL system yielded in Cairo simulation.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	94.6	44.65	14.06	147.2	121.8	271.9	251.1	0.696
February	106.7	58.95	15.73	128.9	99.6	223.8	206.5	0.654
March	157.7	74.60	18.86	164.5	111.8	248.2	228.5	0.567
April	186.7	85.05	21.89	166.9	90.5	199.7	181.3	0.444
May	213.8	92.53	26.09	162.9	68.0	147.6	130.7	0.327
June	219.4	86.03	28.40	163.0	53.6	114.7	98.5	0.247
July	220.1	83.33	29.84	166.4	60.4	128.7	112.2	0.275
August	200.9	83.85	29.93	175.1	82.2	175.6	158.0	0.368
September	170.2	68.40	27.75	178.5	106.9	229.0	209.9	0.480
October	135.9	61.55	24.76	165.8	121.5	261.1	241.0	0.593
November	98.4	45.13	19.95	138.2	113.2	245.4	226.4	0.669
December	86.8	41.71	15.97	135.8	116.1	256.4	236.8	0.712
Year	1891.3	825.79	22.81	1893.2	1145.4	2502.1	2281.0	0.492

Table 9. Normalized performance coefficients of the MPVL system yielded in New York simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	3.67	0.596	3.07	0.250	2.82	0.162	0.068	0.769
February	4.45	0.995	3.45	0.271	3.18	0.224	0.061	0.715
March	4.73	1.536	3.19	0.264	2.93	0.325	0.056	0.619
April	4.91	2.193	2.72	0.253	2.47	0.446	0.052	0.502
May	5.13	2.933	2.20	0.243	1.96	0.571	0.047	0.381
June	5.06	3.048	2.01	0.240	1.77	0.603	0.047	0.350
July	5.04	3.030	2.01	0.236	1.77	0.601	0.047	0.352
August	5.54	2.867	2.67	0.253	2.42	0.518	0.046	0.437
September	4.81	1.923	2.89	0.253	2.64	0.400	0.053	0.548
October	5.30	1.531	3.77	0.287	3.49	0.289	0.054	0.657
November	3.56	0.743	2.82	0.235	2.58	0.209	0.066	0.725
December	3.30	0.525	2.77	0.225	2.55	0.159	0.068	0.773
Year	4.63	1.832	2.80	0.251	2.54	0.396	0.054	0.550

Table 10. Meteo and incident energy of 1 M^2 PV system in New York.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²	DifS_GI ratio
January	56.3	23.45	0.36	3.6	113.7	10.43	5.59	0.000
February	74.7	33.16	1.39	3.7	124.5	13.94	7.44	0.000
March	113.5	52.21	5.97	3.7	146.6	20.68	11.31	0.000
April	142.1	70.36	11.61	3.4	147.3	26.38	14.18	0.000
May	174.2	87.37	16.77	2.8	159.2	31.54	17.41	0.000
June	179.6	90.18	21.47	2.6	151.7	31.73	17.94	0.000
July	176.1	82.91	24.42	2.5	156.3	29.96	17.60	0.000
August	170.4	75.53	24.05	2.3	171.7	27.78	17.01	0.000
September	125.3	62.63	19.84	2.5	144.4	23.86	12.50	0.000
October	106.6	44.45	13.80	2.8	164.4	18.24	10.64	0.000
November	59.5	28.95	8.78	3.1	106.9	12.26	5.92	0.000
December	51.1	25.41	3.20	3.5	102.3	10.86	5.08	0.000
Year	1429.3	676.60	12.70	3.0	1688.8	257.66	142.62	0.000

Table 11. Detailed system losses of the MPVL simulation in New York.

	ModQual	MisLoss	OhmLoss	EArrMPP	InvLoss
	kWh	kWh	kWh	kWh	kWh
January	-1.829	5.055	2.304	233.4	18.99
February	-1.852	5.120	1.994	236.7	18.57
March	-1.895	5.240	1.836	242.4	20.03
April	-1.560	4.312	1.232	199.8	18.60
May	-1.303	3.603	0.760	167.2	18.48
June	-1.149	3.178	0.614	147.5	17.65
July	-1.191	3.292	0.706	152.7	17.96
August	-1.583	4.378	1.212	202.9	19.22
September	-1.660	4.590	1.530	212.4	18.63
October	-2.243	6.201	2.525	286.6	21.82
November	-1.623	4.487	1.926	207.3	17.30
December	-1.650	4.561	1.931	210.7	17.08
Year	-19.538	54.014	18.569	2499.5	224.32

Table 12. Balances and main results of MPVL system yielded in New York simulation.

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	ratio
January	56.3	23.45	0.36	113.7	100.0	233.4	214.4	0.769
February	74.7	33.16	1.39	124.5	100.6	236.7	218.1	0.715
March	113.5	52.21	5.97	146.6	104.3	242.4	222.4	0.619
April	142.1	70.36	11.61	147.3	87.5	199.8	181.2	0.502
May	174.2	87.37	16.77	159.2	74.2	167.2	148.7	0.381
June	179.6	90.18	21.47	151.7	66.6	147.5	129.9	0.350
July	176.1	82.91	24.42	156.3	70.1	152.7	134.8	0.352
August	170.4	75.53	24.05	171.7	93.0	202.9	183.6	0.437
September	125.3	62.63	19.84	144.4	96.5	212.4	193.8	0.548
October	106.6	44.45	13.80	164.4	128.2	286.6	264.7	0.657
November	59.5	28.95	8.78	106.9	91.5	207.3	190.0	0.725
December	51.1	25.41	3.20	102.3	91.4	210.7	193.6	0.773
Year	1429.3	676.60	12.70	1688.8	1104.0	2499.5	2275.2	0.550

3.3 Factors Affecting the MPVL Utilization

According to the results discussed, the topological location impacts the feasibility of MPVL. Not only relying on the solar potential of each cities, there are other governing factors plays in the economic standpoint of MPVL such as panel type, compounding material, capacity, inflation rate and country's policies. The policies in various countries are highly dependent on the countries financial capability to support subsidies, tax policies, monetary policies and price policies. Some countries leading the efforts to switch and adopt renewable energy by implementing different policies such as; feed-in tariffs, tendering, net metering and fiscal incentives. Nevertheless, renewable energy expanding support leads to the deployment of large scale projects. Feed-in tariffs are the most commonly used form of legislative support to the renewable power sector, MPVL utilization maybe favoured on one country than the other, some countries provide more promising opportunities. Such countries optimized the renewable energy policy and renewable energy developments to yield a clear solution to decrease CO_2 emissions. Results confirmed the substantial difference between economic performance on subsidies and non subsidies energy consumption. Financial support is important on building these system. The high initial cost of MPVL discourage people on replacing traditional energy sources from fossil fuel and adopting this green energy alternative sources. Deployment of various policies have been recognized all over the world which culminated a positive growth on the MPVL infrastructures all over the world. However, to make MPVL available as an option in everyone all over the world, the following policies are highly recommended.

- Energy price reform that provides consumers loans for purchasing of MPVL.
- Reduction on fossil fuel subsides, since these policies hinders the deployment and development of MPVL.
- Tax exemption on producers and consumers of green energy.

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- Deployment of MPVL in commercial sector.
- Structural change on the sector that holds a more decisive role on energy production. Tax increase might be considered on fossil fuel produce energy.
- Strategically positioning the MPVL structures on places with long sun hours.
- Public education regarding the importance of replacing fossil fuel based energy with green energy.

These strategies must be employed by the governmental institution decreasing the friction on green energy utilization and fulfilling the responsibility of reducing carbon imprint and fossil fuel based energy. The deployment of MPVL provided an alternative and functional solution. Overall, high installation cost, limited knowledge and lack of governmental subsidy still limits the rampant utilization of MPVL.

4. Conclusions

This article aimed to validate the proposed performance of the MPVL using PVSYST software to design a solar harvesting simulation demonstrated in different geographical locations (Seoul, Cairo, and New York). The findings of the analysis were thoroughly scrutinized to demonstrate the feasibility of MPVL on the exploitation of solar energy on a multi-domain façade. The results also supported the assumption that advanced simulation tools can be used to standardize façade configurations, efficient MPVL system is designed for a grid-connected environment using PVsyst software. The designed MPVL simulation confirmed the viability of installing testing solar harvesting in different topological locations. These findings can be used to validate and will set a basis for MPVL construction feasibility. The analysis not only validated the MPVL configuration but also clear the tradeoffs that affect the energy harvesting efficiency.

References

[1] Pornea AM, Abebe MW, Kim H. Ternary NiCoP urchin like 3D nanostructure supported on nickel foam as a catalyst for hydrogen generation of alkaline NaBH4. Chem Phys 2019;516:152-9.
DOI: https://doi.org/10.1016/j.chemphys.2018.08.044.

[2] Kumar R, Rajoria CS, Sharma A, Suhag S. Design and simulation of standalone solar PV system using PVsyst Software: A case study. Mater Today Proc 2021;46:5322-8.
DOI: https://doi.org/10.1016/j.matpr.2020.08.785.

[3] Ali H. A. Al-Waeli, K. Sopian HAK and MTC. Photovoltaic / Thermal (PV / T) Systems. Int J Comput Appl Sci 2017;2:62-7.

[4] Pornea AM, Kim H. Design and synthesis of SiO2/TiO2/PDA functionalized phase change microcapsules for efficient solar-driven energy storage. Energy Convers Manag 2021;232.
DOI: https://doi.org/10.1016/j.enconman.2020.113801.

[5] Taveres-Cachat E, Lobaccaro G, Goia F, Chaudhary G. A methodology to improve the performance of PV integrated shading devices using multi-objective optimization. Appl Energy 2019;247:731-44.
DOI: https://doi.org/10.1016/j.apenergy.2019.04.033.

[6] Van Helden WGJ, van Zolingen RJC, Zondag HA. PV thermal systems: PV panels supplying renewable electricity and heat. Prog Photovoltaics Res Appl 2004;12:415-26.
DOI: https://doi.org/10.1002/pip.559.

[7] Eltaweel A, Su Y, Lv Q, Lv H. Advanced parametric louver systems with bi-axis and two-layer designs for an extensive daylighting coverage in a deep-plan office room. Sol Energy 2020;206:596-613.
DOI: https://doi.org/10.1016/j.solener.2020.06.035.

[8] Hong S, Choi AS, Sung M. Development and verification of a slat control method for a bi-directional PV blind. Appl Energy 2017;206:1321-33.
DOI: https://doi.org/10.1016/j.apenergy.2017.10.009.

[9] Ramoliya J V. Performance Evaluation of Grid-connected Solar Photovoltaic plant using PVSYST Software. JETIR1502036 J Emerg Technol Innov Res 2015;2:372-8.

[10] Lee M, Hong T, Jeong K, Kim J. A bottom-up approach for estimating the economic potential of the rooftop solar photovoltaic system considering the spatial and temporal diversity. Appl Energy 2018;232:640-56.
DOI: https://doi.org/10.1016/j.apenergy.2018.09.176.

[11] Korsavi SS, Zomorodian ZS, Tahsildoost M. Energy and economic performance of rooftop PV panels in the hot and dry climate of Iran. J Clean Prod 2018;174:1204-14.
DOI: https://doi.org/10.1016/j.jclepro.2017.11.026.

[12] Tuama S, Abdulrazzaq O, Abdulridha S, Faiq N. Investigating the Impact of Tilt Angle, Orientation, and Configuration on PV System Performance Using PVSyst Software. J Appl Sci Nanotechnol 2021;1:73-85.
DOI: https://doi.org/10.53293/jasn.2021.3916.1059.

[13] Choi J, Lee T, Ahn E, Piao G. Parametric louver design system based on direct solar radiation control performance. J Asian Archit Build Eng 2014;13:57-62.
DOI: https://doi.org/10.3130/jaabe.13.57.

[14] Korsavi SS, Zomorodian ZS, Tahsildoost M. Energy and economic performance of rooftop PV panels in the hot and dry climate of Iran. J Clean Prod 2018;174:1204-14.
DOI: https://doi.org/10.1016/j.jclepro.2017.11.026.